DOE/OR/21548-270
CONTRACT NO. DE-AC05-86OR21548

ENGINEERING ANALYSIS OF REMEDIAL ACTION ALTERNATIVES PHASE II

Weldon Spring Site Remedial Action Project
St. Charles, Missouri

NOVEMBER 1992

REV. 0

U.S. Department of Energy
Oak Ridge Field Office
Weldon Spring Site Remedial Action Project

Printed in the United States of America. Available from the National Technical Information Service, NTIS, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161

NTIS Price Codes - Printed copy:
Microfiche: A01

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MK-FERGUSON A MORRISON KNUDSEN COMPANY Weldon Spring Site Remedial Action Project Contract No. DE-AC05-86OR21548	Rev. No. 0
PLAN TITLE: Engineering Analysis of Remedial Action Alternatives, Phase II	

APPROVALS

Department Manager — Date: 12-22-92

Quality Assurance Manager — Date: 01/06/93

Deputy Project Director — Date: 1-7-93

Project Director — Date: 1/8/93

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DOE/OR/21548-270

Weldon Spring Site Remedial Action Project

Engineering Analysis of Remedial Action Alternatives Phase II

Revision 0

November 1992

Prepared by

MK-FERGUSON COMPANY
and
JACOBS ENGINEERING GROUP
7295 Highway 94 South
St. Charles, Missouri 63304

for the

U.S. DEPARTMENT OF ENERGY
Oak Ridge Field Office
Under Contract DE-AC05-86OR21548

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1 INTRODUCTION

1.1 Purpose

This report, the *Engineering Analysis of Remedial Action Alternatives, Phase II* (Phase II EAA), provides technical information to support the *Feasibility Study for Remedial Action at the Chemical Plant Area of the Weldon Spring Site* (FS) (DOE 1992a) prepared by Argonne National Laboratory (ANL). The focus of the Phase II EAA is on the five alternatives retained for detailed analysis in the FS: no further action (1); removal, chemical solidification/ stabilization with on-site disposal (6A); removal, vitrification with on-site disposal (7A); removal, vitrification with off-site disposal at Clive, Utah (7B); and removal, vitrification with off-site disposal at Richland, Washington (7C). Specific information regarding each of these five alternatives is presented to support the detailed evaluation and comparative analysis of alternatives in the FS. It should be noted that the costs and design concepts presented throughout this Phase II EAA report for the various remedial technologies are preliminary in nature. A companion document, the *Engineering Analysis of Remedial Action Alternatives, Phase I* (Phase I EAA) (MKF and JEG 1992a), presents engineering information for a range of potential treatment and containment options to support the FS screening process.

1.2 Report Organization

The sources, quantities, and primary contaminants of the Weldon Spring wastes are discussed in Section 1.3 of this report. Section 2 provides a discussion of the primary waste treatment technologies, chemical stabilization and vitrification, evaluated in the FS. Section 3 summarizes the alternative development process and the remedial action alternatives retained for detailed evaluation. A detailed operational description for each of the five alternatives retained is presented in Section 4. For comparative purposes, Alternative 1 - No Further Action is included as one of the five remedial action alternatives under consideration, consistent with CERCLA guidance criteria for evaluation.

The effectiveness of the five remedial action alternatives is addressed in Section 5. This section includes a discussion on the amount of hazardous materials treated or destroyed; the reduction in toxicity, mobility, and volume; irreversibility of treatment; and type and quantity of residuals.

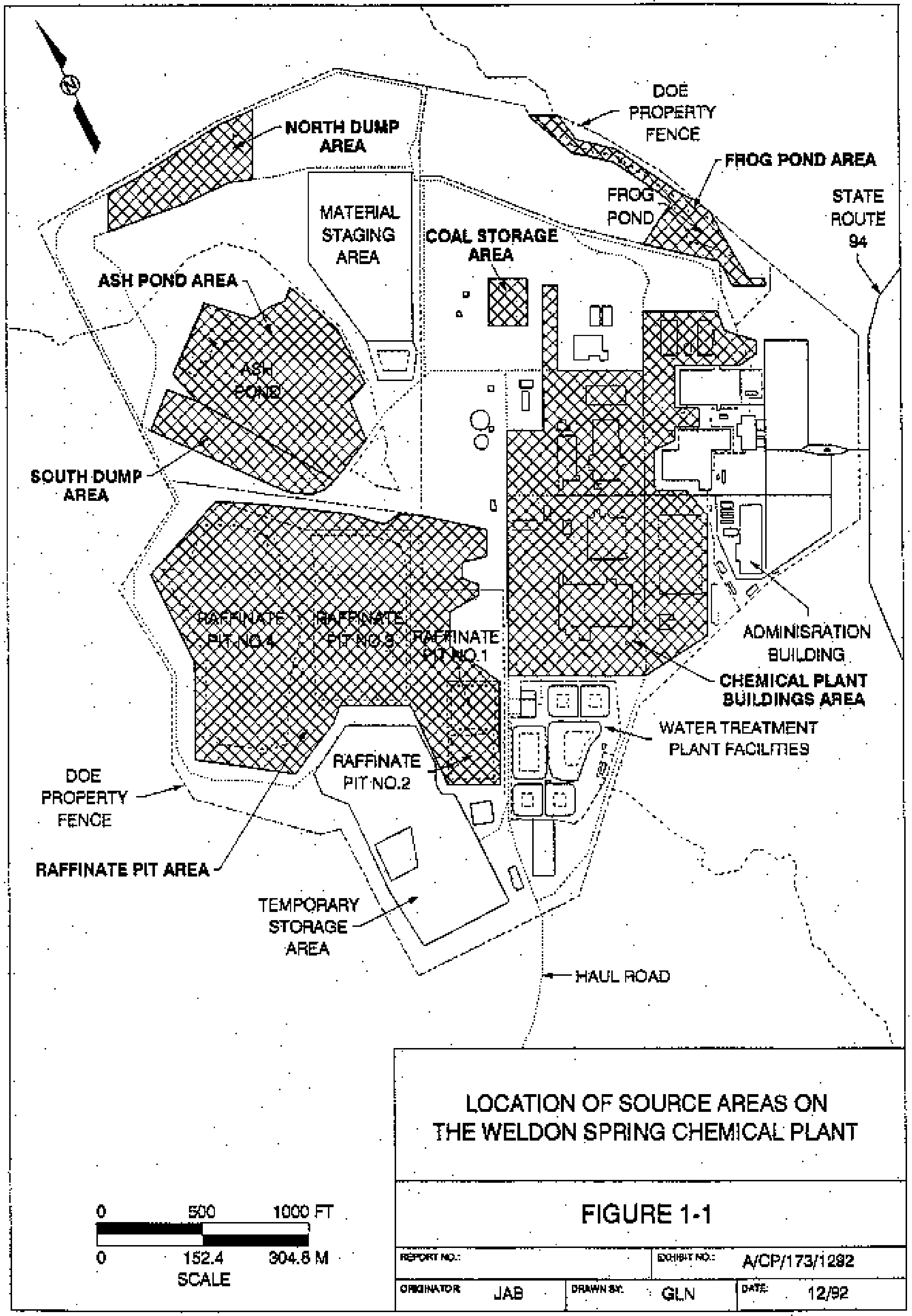
Section 6 presents the adequacy and reliability of controls associated with each remedial action alternative. Section 7 discusses implementability of the alternative technologies and disposal options and addresses availability of technology, equipment, and specialists; constructibility and operability; reliability of the technology; ease of undertaking additional remedial action; and the ability to monitor effectiveness. The time required to implement each of the alternatives is presented in Section 8; a cost analysis summary is provided in Section 9.

Documents used to support preparation of this report are referenced in Section 10, acronyms and abbreviations in Section 11, and symbols of elements and chemical compounds in Section 12. More detailed cost information is contained in Appendix A, Alternatives Summary Cost Estimate.

1.3 Waste Materials and Source Descriptions

The quantities and primary contaminants of the following Weldon Spring waste materials and source areas are described is this section. Waste quantities for the chemical plant area and vicinity properties were estimated based on the reference level of 15 pCi/g of uranium presented in the *Remedial Investigation for the Chemical Plant Area of the Weldon Spring Site* (RI) (DOE 1992b). This document was initiated before actual cleanup values had been developed as part of the FS process. Therefore, the volumes estimated in this report are preliminary estimates and are conservative on the upper range. Contaminant source locations and storage areas are illustrated on Figures 1-1, 1-2, and 1-3, and are listed below.

- Raffinate pits.
- North dump.
- South dump.
- Coal storage.
- Temporary storage area (TSA).
- Material staging area (MSA).
- Ash Pond spoils pile.
- Mulch pile.



LOCATION OF SOURCE AREAS ON THE WELDON SPRING CHEMICAL PLANT

FIGURE 1-1

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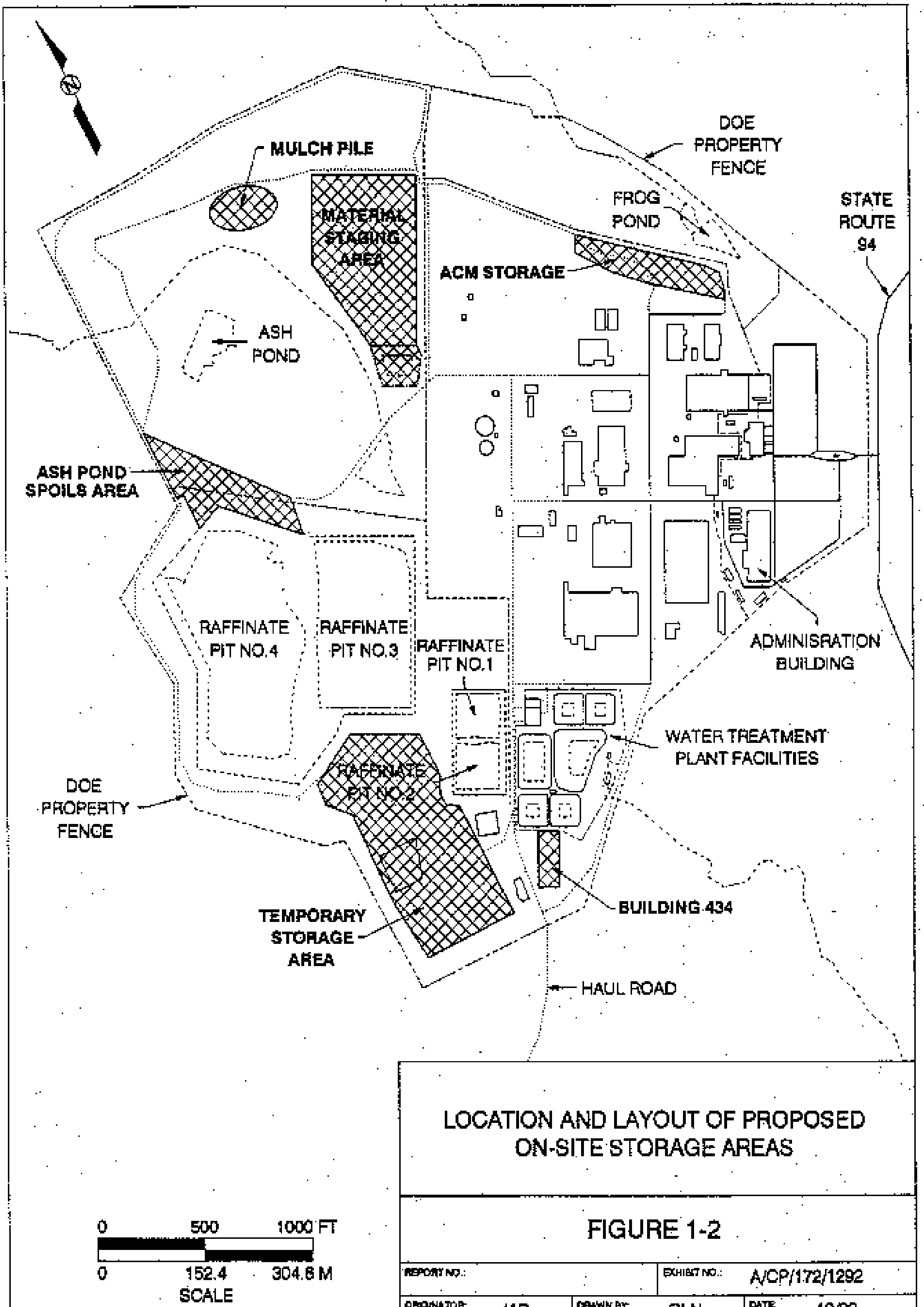

LOCATION AND LAYOUT OF PROPOSED ON-SITE STORAGE AREAS

FIGURE 1-2

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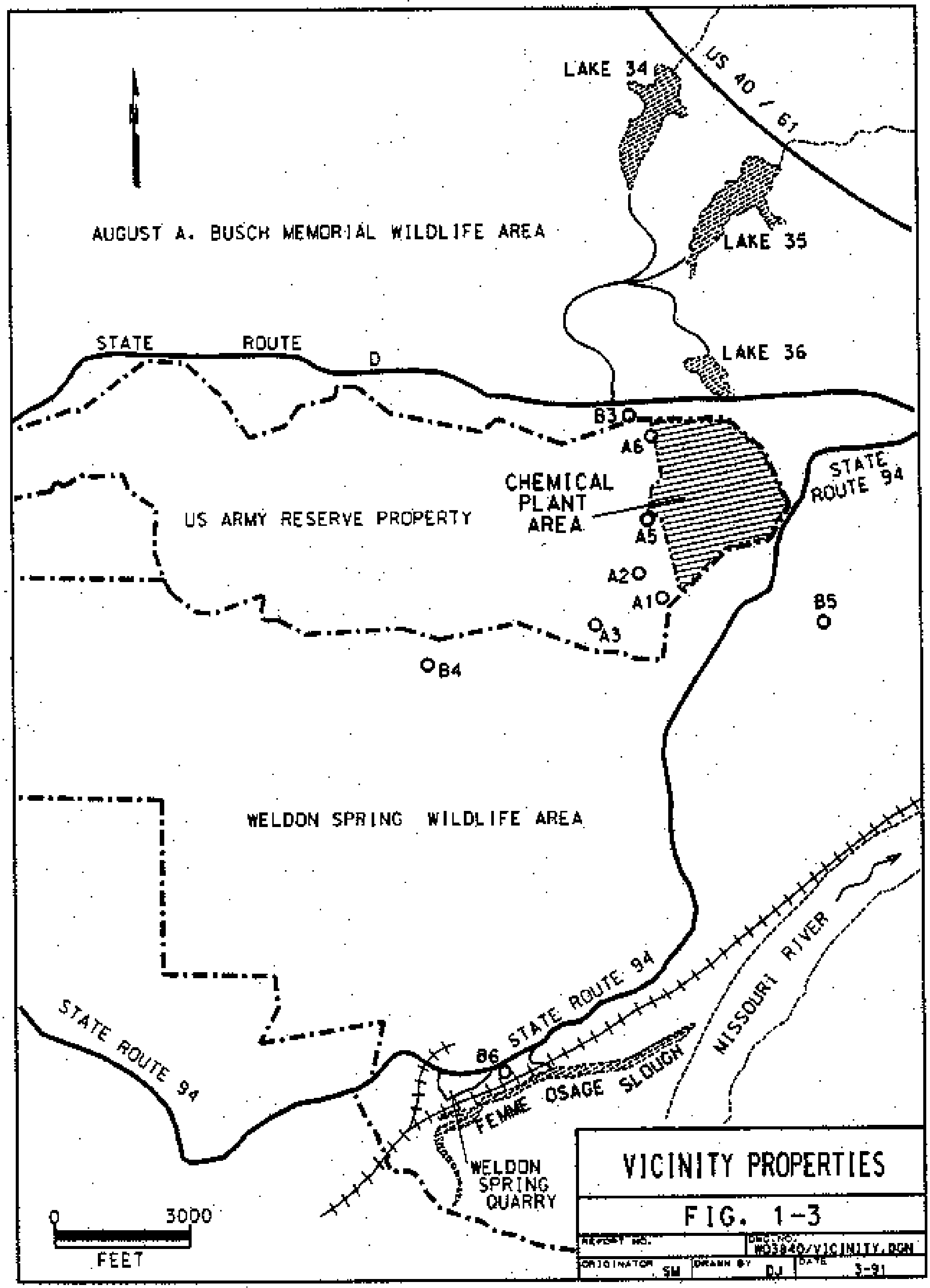

VICINITY PROPERTIES

FIG. 1-3

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- Asbestos-containing material (ACM) storage area.

- Building 434.

- Building foundations and underground piping and sewers in chemical plant buildings area.

- Vicinity properties.

Areas being remediated under separate response actions, such as the Southeast Drainage and Femme Osage Slough, are not included in the scope of this analysis.

It should be noted that waste material quantities associated with the source locations and storage areas shown above will likely change as more definitive characterization is performed for remedial design. Preliminary design concepts, cost estimates, and schedules using these quantities may also change.

1.3.1 Raffinate Sludges

During site operations, the Weldon Spring raffinate pits received process wastes from the chemical plant. Pits 1, 2, and 3 contain raffinate sludge resulting from refining of uranium ore concentrate and disposal of scrap metal. In addition to sludge, pit 4 contains thorium processing wastes and drums and rubble from partial demolition of the plant. These four pits cover 25.8 acres and contain approximately 220,000 cubic yards of contaminated sludges. Contaminant value ranges for radionuclides and inorganic ions present in the sludge are listed in Table 1-1, and metals concentrations are listed in Table 1-2.

1.3.2 Soils and Sediments

An estimated 302,200 cubic yards of contaminated soils and sediments are in place at the locations described in the following sections. Radionuclide concentrations detected in these areas are included in each discussion. The volumes of soil presented are based on the 15 pCi/g reference level discussed in the site RI Report (DOE 1992b) and do not represent volumes based on actual cleanup criteria. Cleanup levels are presented in Section 2 of the site FS document (DOE 1992a). Distribution of chemical contaminants in soils and sediments are addressed in Section 5 of the site RI Report (DOE 1992b).

TABLE 1-1 Raffinate Sludge Contaminant Value Ranges

Contaminant	Minimum	Maximum
Radionuclides		
Total Uranium	10 pCi/g	3,400 pCi/g
Thorium-230	8 pCi/g	34,000 pCi/g
Thorium-232	3 pCi/g	1,400 pCi/g
Radium-226	1 pCi/g	1,700 pCi/g
Radium-228	4 pCi/g	1,400 pCi/g
Inorganic Ions		
Nitrite	ND	1,640 µg/g
Nitrate	ND	161,000 µg/g
Sulfate	ND	7,683 µg/g
Chloride	2 µg/g	296 µg/g
Fluoride	ND	165 µg/g

ND = Not Detected
Source: Modified from DOE 1992b.

TABLE 1-2 Raffinate Sludge Metals Summary

Contaminant	Minimum	Maximum
Aluminum	ND	28,700 µg/g
Antimony	ND	87 µg/g
Arsenic	3 µg/g	1,060 µg/g
Barium	ND	7,740 µg/g
Beryllium	ND	25 µg/g
Cadmium	ND	321 µg/g
Calcium	ND	86,100 µg/g
Chromium	ND	169 µg/g
Cobalt	ND	441 µg/g
Copper	4 µg/g	511 µg/g
Iron	30 µg/g	22,800 µg/g
Lead	ND	644 µg/g
Lithium	ND	122 µg/g
Magnesium	ND	17,110 µg/g
Manganese	ND	3,010 µg/g
Mercury	ND	15 µg/g
Molybdenum	ND	1,800 µg/g
Nickel	11 µg/g	8,790 µg/g
Potassium	ND	1,470 µg/g
Selenium	ND	81 µg/g
Silver	ND	5 µg/g
Sodium	ND	23,800 µg/g
Thallium	ND	58 µg/g
Vanadium	ND	26 µg/g
Zinc	8 µg/g	1,580 µg/g
Zirconium	ND	2,120 µg/g

ND = Not Detected
Source: Modified from DOE 1992b.

1.3.2.1 Ash Pond. During site operations, Ash Pond received fly ash slurry from the power plant. Ash pond, which covers a 376,345-square-foot area, contains approximately 8,200 cubic yards of contaminated sediment and soil. The sediment is contaminated with uranium and nitrate, and the underlying soil may also be contaminated with uranium as a result of contact with the contaminated surface water and sediment. The primary contaminant of concern is uranium-238, with concentrations ranging from 0.3 pCi/g to 14 pCi/g (DOE 1992b). Above background concentrations of radium-226 are present and range from 3.8 to 6.5 pCi/g. The combination of uranium and radium contamination in parts of the Ash Pond area result in above-mixture-rule concentrations as discussed in Section 5.2.2 of the site RI Report (DOE 1992b).

1.3.2.2 Frog Pond. Frog Pond previously received flow from storm and sanitary sewers at the chemical plant. This 81,338-square-foot area contains an estimated 7,000 cubic yards of contaminated soil and sediment. Uranium-238 concentrations in the sediment range from 0.3 pCi/g to 280 pCi/g (DOE 1992b). Soil in the berm and beneath the pond is expected to contain elevated concentrations of uranium and chloride resulting from contact with and leaching from the sediment and surface water.

1.3.2.3 Busch Lakes 34, 35, and 36. Lakes 34, 35, and 36, located in the Busch Wildlife Area, receive runoff and groundwater recharge from the Weldon Spring site. These three lakes contain an estimated 20,000 cubic yards of uranium-contaminated sediment: 8,000 cubic yards in Lake 34, 5,000 cubic yards in Lake 35, and 7,000 cubic yards in Lake 36. Analyses of samples collected from Lake 34 showed average uranium-238 concentrations in the sediment ranging from 3.0 pCi/g to 46.8 pCi/g. Average values in samples from Lakes 35 and 36 ranged from 1.0 pCi/g to 23.6 pCi/g and 11.4 pCi/g to 30.3 pCi/g, respectively (DOE 1992b).

1.3.2.4 North Dump. Radioactive scrap material and drums were previously stored at the North Dump. The 82,506-square-foot North Dump area now contains approximately 7,600 cubic yards of contaminated sediment and soil. Uranium-238 concentrations at the North Dump range from 0.3 pCi/g to 1,380 pCi/g (DOE 1992b).

1.3.2.5 South Dump. The South Dump covers 182,290 square feet and contains approximately 16,900 cubic yards of radioactively contaminated soils resulting from prior disposal of contaminated equipment, yellow cake drums, personal protective equipment, and other refuse. Uranium-238 concentrations in the South Dump soils range from 0.3 pCi/g to 2,105 pCi/g; thorium-230 concentrations range from 0.8 pCi/g to 123 pCi/g (DOE 1992b).

1.3.2.6 Raffinate Pits. An estimated 153,500 cubic yards of soil beneath the pits and in the berms is expected to contain elevated concentrations of the contaminants listed in Tables 1-1 and 1-2. This volume estimate includes 50,000 cubic yards of soil that will require treatment. Contamination in this 1,123,848-square-foot area is the result of contact with and leaching from the pit sludges and surface water. To more accurately identify the contaminant types and concentrations in the raffinate pit bottom soils, additional characterization will be performed after the surface water and sludge are removed.

1.3.2.7 Other On-Site Surfaces. In addition to the specific source areas identified above, an additional 85,400 cubic yards of contaminated soil are present around and beneath the chemical plant buildings and in open areas, including the former coal storage area. The area around the chemical plant buildings encompasses 1,530,985 square feet. The areas adjacent to the chemical plant were previously used to unload and store process material, to house electrical equipment, and to contain soil contaminated with uranium, thorium, radium, sulfate, nitrate, pesticides, polynuclear aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs). Past spills and overland flow have contaminated the soils in the areas adjacent to the raffinate pits with uranium, thorium, fluoride, sulfate, and nitrate. An estimated 20,000 cubic yards of the above total is comprised of contaminated soil surrounding underground piping.

1.3.2.8 Vicinity Properties. Approximately 3,600 cubic yards of uranium-contaminated soil are present on vicinity properties associated with the Weldon Spring chemical plant site. Vicinity properties comprise certain areas which are near the raffinate pits and the chemical plant and quarry sites, but which are outside current fenced boundaries, and contaminated properties located along ditches, drainage ways, roads, and railroads. These vicinity properties include Army properties 1, 2, 3, 5, and 6 (3,100 yd^3) and Busch properties 3, 4, 5, and 6 (500 yd^3). Uranium-238 concentrations in these soils range from less than 0.5 pCi/g to 29,530 pCi/g (DOE 1992b).

1.3.3 Raffinate Pit Rubble

An estimated 500 cubic yards of concrete, tanks, barrels, containers, pipe, wood, and structural elements are present on the east bank of Raffinate Pit 4. Material is also present on the north and west banks.

1.3.4 Temporary Storage Area

An estimated 150,400 cubic yards of contaminated material will be stored at the 544,500-square-foot TSA. Included in this amount are 96,800 cubic yards of bulk waste excavated from the Weldon Spring quarry. These quarry bulk waste materials include:

- Metal building and equipment debris (10,500 yd^3).
- Concrete building debris (30,200 yd^3).
- Contaminated quarry soil and sediment (52,000 yd^3).
- Contaminated quarry sludge/sediments (4,100 yd^3).

Chemical and radioactive contamination at the Weldon Spring quarry is the result of disposal practices during past site operations. Uranium, thorium, radium, and radon are the radioactive constituents of concern. Average radionuclide concentrations in the quarry soils are 108 pCi/g for radium-226, 380 pCi/g for thorium-230, 198 pCi/g for uranium-238, 96 pCi/g for radium-228, and 26 pCi/g for thorium-232 (DOE 1989). Average radionuclide concentrations in the quarry pond sediments are 905 pCi/g for uranium-234, 107 pCi/g for uranium-235, 889 pCi/g for uranium-238, and 316 pCi/g for thorium-230 (DOE 1989). Known chemical contaminants include nitroaromatic compounds, PAHs, PCBs, and heavy metals.

In addition to the quarry materials, approximately 50,000 cubic yards of raffinate pit soil will be stored at the TSA for future transfer to the treatment plant. Planning optimization may reduce this volume through direct delivery to the treatment facility. Approximately 3,600 cubic yards of containerized residues generated during operation of the water treatment plants at the chemical plant site (3,100 yd^3) and the quarry (500 yd^3) will also be stored at the TSA. These residuals may be contaminated with radionuclides, arsenic, manganese, fluoride, and nitroaromatics (2,4-DNT).

1.3.5 Material Staging Area

The MSA will be used to store approximately 77,078 cubic yards of radioactively contaminated materials resulting from building demolition and site debris consolidation. These materials will include:

- Nonfriable ACM removed from buildings prior to dismantlement (5,111 yd^3).

- Debris and rubble from building dismantlement (71,967 yd^3) consisting of concrete block and concrete rubble (18,223 yd^3), metal (51,385 yd^3), solid wood and wood furniture (2,078 yd^3), and miscellaneous other debris (281 yd^3).

As an alternative, the concrete block and rubble may be stored in an expanded Ash Pond spoils pile.

1.3.6 Ash Pond Spoils Pile

The 4.1-acre (180,000 ft^2) Ash Pond spoils pile will serve as a temporary storage and staging area for contaminated soils removed during site preparation activities which cannot be transported directly to an on-site disposal facility or to a staging area for off-site transport. The 5,800 cubic yards of material currently in place include:

- Contaminated soil removed during site preparation for the TSA (4,100 yd^3). Uranium-238 contamination in the soil ranges from less than 2.4 pCi/g to 2,259.3 pCi/g (DOE 1992b).

- Contaminated soil removed during site preparation for the site water treatment plant (1,700 yd^3). The soil from this 91,321-square-foot area contains above-reference-level concentrations of thorium-230 and uranium-238 to a depth of 6 inches.

1.3.7 Mulch Pile

The mulch pile is located in the northeast portion of the site and may be used for composting cleared and grubbed material and other organic debris from the chemical plant site and the quarry. The 30,652 cubic yards of material include:

- Chipped vegetation from the quarry (5,300 yd^3).
- Chipped railroad ties (1,200 yd^3) from initial quarry cleanup activities.
- Chipped debris from clearing and grubbing at the raffinate pits (5,900 yd^3).
- Chipped debris from clearing and grubbing at the chemical plant area (17,500 yd^3).
- Paper debris removed during building dismantlement activities (2 yd^3).
- Chipped railroad ties from the chemical plant area (750 yd^3).

It is anticipated that final disposition of these materials will be direct placement in the disposal facility or transport to a staging area for off-site disposal.

1.3.8 ACM Storage Area

An estimated 1,483 cubic yards of friable ACM has been double bagged and is being temporarily stored on site in Building 103. Approximately 20 pieces of equipment containing small quantities of asbestos are also stored in Building 103. All friable asbestos will be containerized and stored within an area proposed to the north of Buildings 403 and 404. This ACM storage area is depicted in Figure 1-2. This area will be used for another 3,233 cubic yards of friable ACM located throughout the site buildings which will be removed, bagged, and stored along with the ACM relocated from Building 103.

1.3.9 Building 434

Building 434 is being used as a RCRA/TSCA storage facility in support of various interim response actions. The facility includes a central storage building and several annex units. The 5,139 cubic yards of waste materials which are or will be stored in this facility include:

- Approximately three hundred 55-gallon drums of waste including paints, solvents, and oils (111 yd^3).

- Approximately one hundred 55-gallon drums (28 yd^3) of containerized chemicals including nitric and sulfuric acid, sodium hydroxide, flammable and reactive solids, and oxidizers which will be deactivated on site prior to disposal.

- Used personal protective equipment (5,000 yd^3, uncompacted, over a 10-year period).

- Approximately 1,400 drums (330 yd^3) of radioactively contaminated materials (primarily soils) that are not regulated but are above site release levels. It is anticipated that these materials will be treated in an on-site facility.

The used personal protective equipment (PPE) is being compacted and drummed as it is placed in storage. As the PPE is radioactively contaminated only, it could also be stored at the MSA. However, the material is being stored in the Building 434 facility due to greater control over storage conditions. All materials that are flammable are being stored in an annex unit rather than the main Building 434 structure.

Although not currently in Building 434, 7,400 gallons of tributyl phosphate stored in on-site tanks may be moved to this facility as an alternative storage strategy. A catchment has been constructed around the tanks and they are monitored on a routine basis.

1.3.10 Building Foundations and Underground Piping and Sewers

Building foundations and underground piping beneath the chemical plant area are chemically and radioactively contaminated. The quantity of material is estimated to be 40,591 cubic yards of concrete foundation and 1,309 cubic yards (64,240 lineal feet) of 12-inch-diameter (average) concrete and clay piping. This material will be stored in the MSA, or alternatively, the concrete may be stored in an expanded Ash Pond spoils pile.

1.3.11 Roads and Embankments

If a removal, on-site treatment, and disposal alternative is implemented, as much as 76,930 cubic yards of road materials and aggregates may be used to stabilize working surfaces in the raffinate pits and to construct retention dikes. These materials may become contaminated during operations; if so, they will be reclaimed and placed within an on- or off-site disposal cell. These materials include:

- 15,400 yd^3 of aggregate bottom stabilization in the raffinate pits.
- 10,800 yd^3 of raffinate roads.
- 1,830 yd^3 of retention pond material.
- 1,800 yd^3 of access road from vicinity properties Army 5 and 6.
- 4,000 yd^3 of aggregate bottom stabilization in Ash Pond.
- 800 yd^3 of aggregate bottom stabilization in Frog Pond.
- 25,900 yd^3 of water control dikes and sediments.
- 16,400 yd^3 of chemical plant roads and work areas.

1.3.12 Facilities Closure

Facilities closure will involve the removal and size reduction of an estimated 38,300 cubic yards of building materials, if a removal and on-site waste treatment remedial action alternative is implemented. The following volumes are included:

- 22,000 yd^3 TSA foundation.
- 400 yd^3 site water treatment plant.

- 14,500 yd^3 MSA foundations.
- 900 yd^3 waste treatment facility.
- 500 yd^3 volume reduction facility.

1.3.13 Waste Materials and Quantities Summary

The estimated in-place quantities of the waste materials are summarized in Table 1-3. It should be noted that these quantities will likely change as more definitive characterization is performed during remediation design.

TABLE 1-3 Waste Material Quantities

Material/Source	Quantity	Tonnage
Raffinate Sludge	220,000 yd^3	222,200
Soils and Sediment		
• Ash Pond	8,200 yd^3	12,460
• Frog Pond	7,000 yd^3	10,640
• Lakes 34, 35, 36	20,000 yd^3	30,400
• North Dump	7,800 yd^3	11,550
• South Dump	16,900 yd^3	25,690
• Raffinate Pits	153,500 yd^3	233,320
• Other On-Site Surfaces	85,400 yd^3	129,810
• Vicinity Properties	3,600 yd^3	5,470
Raffinate Pit Rubble	500 yd^3	3,310
TSA	100,400 yd^3	220,040
MSA	77,078 yd^3	61,665
Ash Pond Spoils Pile	5,800 yd^3	8,810
Mulch Pile	30,652 yd^3	19,151
ACM Storage Area	4,718 yd^3	2,929
Building 434	5,469 yd^3	1,535
Building Foundations and Underground Sewers	41,900 yd^3	63,931
Subtotal	788,715 yd^3	1,082,928
Roads and Embankment Removal	76,930 yd^3	116,930
Facilities Closure	38,300 yd^3	78,210
Subtotal	115,230 yd^3	195,140
TOTAL WASTE VOLUME	903,945 yd^3	1,278,068

Source: MKF and JEG 1991b.

2 DESCRIPTION OF TREATMENT TECHNOLOGIES

This section provides additional detail regarding the chemical solidification/stabilization and vitrification treatment technologies described in the *Engineering Analysis of Remedial Action Alternatives, Phase I* (MKF and JEG 1992a). These technologies represent the primary treatment options considered for detailed analysis in the feasibility study (FS) (DOE 1992a) prepared by Argonne National Laboratory for the Weldon Spring chemical plant area.

2.1 Chemical Solidification/Stabilization

Chemical stabilization of removed material involves mixing reagents with contaminated material to solidify the media and immobilize the contaminants. Although contaminants are immobilized, they are not destroyed. Common stabilization reagents include Portland cement, fly ash, lime, bentonite, vermiculite, gypsum, carbon, zeolites, cellulosic sorbents, and soluble sodium or potassium silicates (Rich and Cherry 1987). The cement-based CSS process option using Portland cement and fly ash is evaluated and identified in the FS (DOE 1992a) as the optimal chemical stabilization technology for remediation of the Weldon Spring site.

Cement-based solidification, the mixing of wastes directly with Portland cement, is a well established remedial technology (Rich and Cherry 1987). Most solidification is accomplished using Type I Portland cement, but Types II and V can be used for stabilizing sulfate- or sulfite-containing materials. Due to the sulfate content, Type II is recommended for solidification of the Weldon Spring raffinate sludges. Commonly, siliceous compounds, including fly ash, blast furnace slag, soluble sodium or potassium silicates, and proprietary agents are used in conjunction with Portland cement. A major limitation with silicate-only (i.e., not combined with cement-based) processes is that a large amount of non-chemically bound water remains in the solidified product. To prevent the escape of this water, a silicate-only solidified product would likely require some kind of secondary containment (Rich and Cherry 1987). Therefore, the use of a cement-silicate mixture is recommended.

Portland cement can absorb significant quantities of water during hydration reactions. The addition of Portland cement can chemically incorporate otherwise drainable water into hydrated phases. A mixture of silicates and cement can stabilize a wide range of materials including metals, waste oil, and solvents, often better than either agent alone. For example, it is known that cement alone (i.e., not in combination with silicates) is not effective in immobilizing organics; therefore, cement alone would likely not effectively immobilize the nitroaromatic-contaminated quarry soils (Rich and Cherry 1987).

Oak Ridge National Laboratory specialists assessed the applicability of cement-based solidification/stabilization technology as part of a remedial action option for the raffinate pits (Gilliam and Francis 1989). The results of the study suggested that a blend consisting of 40 weight percent Type II Portland cement and 60 weight percent ASTM Class F fly ash be combined with the raffinate sludge at a mix ratio of 0.6 g/g (grams of dry-solids blend per gram of raffinate). The solidified mass met the performance criteria of no drainable water within 28 days, an unconfined compressive strength above 50 psi, and resistance to thermal cycling. The grout blend ratios can be adjusted to accommodate expected variations in the waste composition or more stringent future performance criteria by implementing minor processing operational changes which are well within the capability of standard commercially available technology (Gilliam and Francis 1989). However, a wide range of setting rates, duration of drainable water, unconfined compressive strengths with variations in reagent blend additions, and water content were observed in the raffinate sludge samples (Gilliam and Francis 1989). These observations suggest that stringent quality control procedures be implemented to ensure that a stable product is produced.

Mixing can be accomplished using commercial cement mixing equipment such as ribbon blenders, and single- or double-shaft mixers (Rich and Cherry 1987). Equipment requirements include chemical storage hoppers, weight- or volume-based chemical feed equipment, mixing equipment, and waste handling equipment.

A range of contaminant release rates from cement-stabilized masses have been reported. Bishop (1989) suggests that the rate of contaminant leaching should be very slow, allowing contaminants to disperse over long periods of time. Rich and Cherry (1987) indicate that the end product of cement solidification will not be acceptable for disposal without secondary containment regardless of whether the wastes are organic or inorganic in nature. These authors also note the uncertainty regarding the long-term stability of the solidified concrete mass. The placement of any bulk or non-containerized liquid wastes or wastes containing free liquids was banned effective May 8, 1985, 40 CFR 264.314(b). Free liquids are defined as liquids which readily separate from the solid portion of a waste under ambient temperature and pressure [40 CFR 260.10]. In accordance with 40 CFR 264.314(c), the absence or presence of free liquids must be determined by using Method 9095, Paint Filter Liquids Test, as described in *Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods* (EPA Publication No. SW-846).

2.2 Vitrification

Technology screening studies performed in support of the FS are presented in the *Engineering Analysis of Remedial Action Alternatives, Phase I* (MKF and JEG 1992a). These studies indicated that fossil fuel-heated ceramic melters, joule-heated ceramic melters, and plasma arc torch units were all potentially viable vitrification processes. Slagging incinerators and high-temperature joule-heated ceramic melters were eliminated from consideration because of refractory corrosion and an inability to tolerate metal immiscibility. Fossil fuel-heated ceramic melters (FFHCM) have a significantly lower operating cost and are more tolerant of changes in melt viscosity, conductivity, and metal phase immiscibility. The FFHCM process option is evaluated and identified in the FS (DOE 1992a) as the optimal vitrification technology for remediation of the Weldon Spring site.

The vitrified product is a leach-resistant material which undergoes a significant volume reduction. Volume reduction is typically 20% to 40%. The reduced volume is the result of the loss of intergranular pore space, water, and volatile and semi-volatile organic compounds existing in the original material. The degree of volume reduction is dependent on the amount of feed additives necessary for the particular process. Joule-heated ceramic melters generally require additives to modify the electrical conductivity and viscosity of the melt. Incinerators, fossil fuel-heated ceramic melters, and plasma arc torch processes generally do not require additives and, consequently, typically achieve higher volume reductions than joule-heated ceramic melters.

Vitrification processing methods require sufficient glass-forming materials such as silicon and aluminum oxides to form a leach-resistant product. This requirement can be satisfied by adding fluxing materials to the feed material. Exposure to high temperature causes contaminant materials to break down or to react with and be chemically incorporated into the vitrified product. Near optimum melt conditions can be achieved in the vitrification process by most naturally occurring soils, sediments, and tailings, and by many process sludges.

The chemical composition of the material to be vitrified determines the melt characteristics and the leachability of the final product. Increasing the silica content of the feed increases the viscosity of the melt. Increased silica also reduces the solubility of waste materials in the melt, but greatly increases the durability of the final glass product. Addition of boric oxide (B_2O_3) increases the solubility of waste in the melt and reduces the viscosity of the melt. The boric acid also retards devitrification in the final glass product, but reduces the overall durability of the product. Increases in calcium oxide (CaO) content increases the leachability of the final glass product (Plodinec 1986; Marples 1988).

Melt temperatures vary with the thermal method and the fuel or heat source chosen for vitrification. Temperatures obtained for the solid materials treated range from approximately 800°C for rotary kiln incineration to 3000°C for the plasma arc torch melting process. At these temperatures, organic compounds are destroyed. Depending on the composition of the waste material and additives, some volatilization of constituents of the waste may occur. The lower temperature methods typically have secondary combustion chambers to ensure complete destruction of the organic compounds present in the waste treated. An off-gas collection system is needed for NO_X, SO_X, and other potentially volatilized components such as arsenic, cadmium, cesium, fluorine, mercury, and radon. Conventional off-gas collection methods include electrostatic precipitation, pH neutralized wet scrubber, HEPA filtration, and carbon adsorption. Certain off-gas treatment waste may be recycled to subsequent vitrification processes. However, alternative disposal methods for some off-gas treatment waste will also be required.

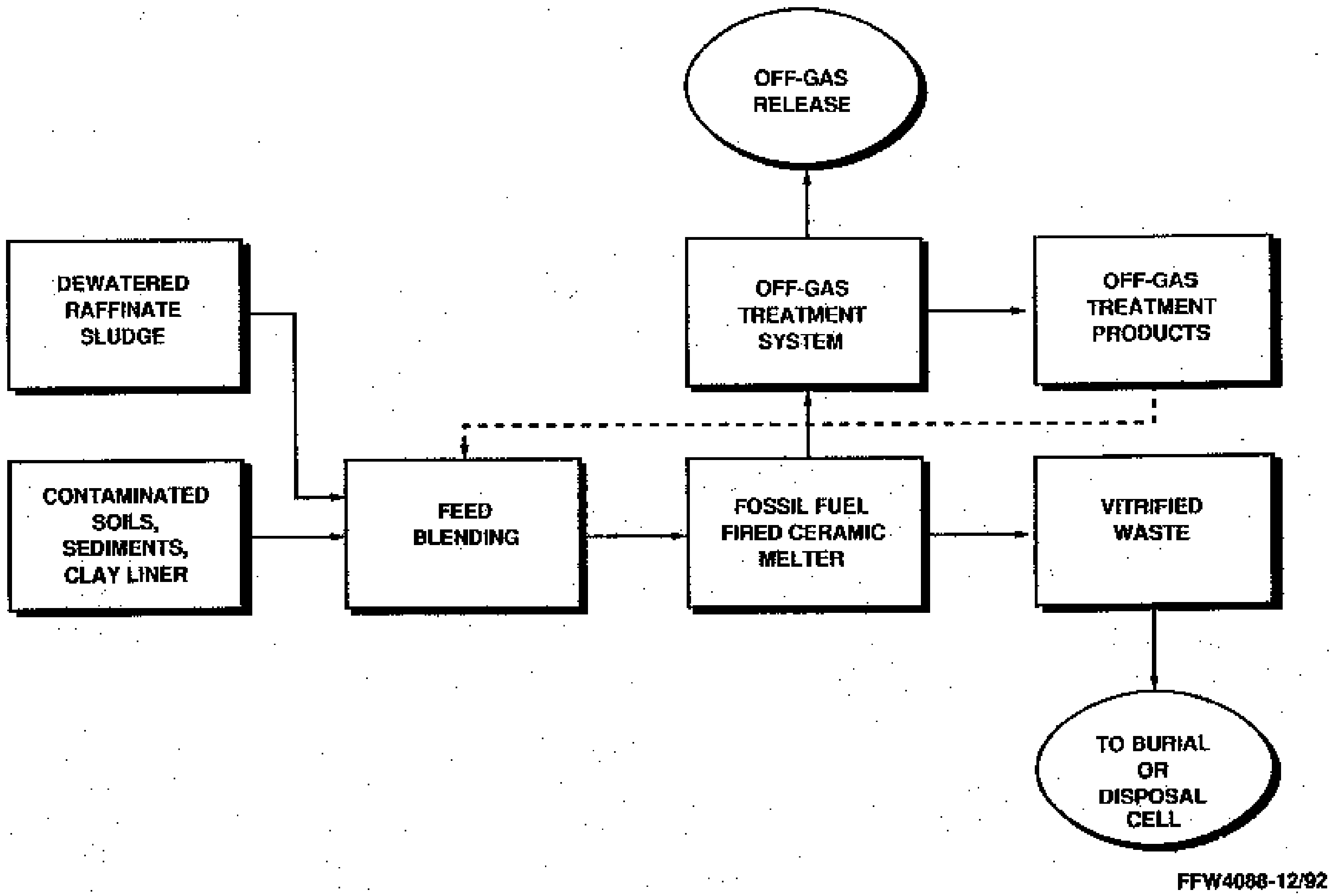
2.2.1 Fossil Fuel-Heated Ceramic Melting Process

The fossil fuel-heated ceramic melting (FFHCM) process, as applied to hazardous waste treatment, is a stabilization/destruction process which vitrifies waste materials through the use of fossil fuel energy. The process is illustrated in Figure 2-1.

The FFHCM process is an adaptation of commercial glass-making technology. Contaminated soil or sludge is fed into an enclosed melter and melted by heating with a fossil fuel-generated flame. The addition of an oxidant gas to the fossil fuel is required to generate a flame. This gas is usually air, but may be supplemented by oxygen to increase the temperature of the flame. Temperatures of up to 1900°C can be obtained in the melt (Vortec 1990). At such temperatures, organic compounds are easily destroyed. Optimum process conditions occur when the melting temperature is between 1,070°C and 1,250°C, the mixture has a viscosity of 100 poise (Marples 1988), and the electrical conductivity is between 0.18 and 0.5 ohm-cm^{-1} (Koegler et al. 1989). Unlike JHCM processing, melt conductivity is not important.

Air emissions could result from the volatilization of waste constituents and the combustion of the fossil fuels. Combustion of fossil fuels might cause a higher level of NO_x and SO_X in the flue gas than could be normally attributed to the waste. Emissions from the

FIGURE 2-1 PROCESS FLOWSHEET FOR FOSSIL FUEL-FIRED CERAMIC MELTING



melter could be reduced through the use of plasma arc torch boosting or joule heating electrode boosting. The latter is the most common method of emissions reduction for fossil fuel-heated melters in the glass industry. A conventional off-gas collection system may also be used.

Vortec Inc., an FFHCM vendor, employs patented and patent-pending processes which are refinements of the fuel-fired glass-making processes. Vortec claims that their furnaces can easily achieve the temperatures required to melt Weldon Spring materials.

One of Vortec's refinements on fuel-fired melters is a more efficient heat exchanger for the recovery of heat energy from the off-gas stream. This development significantly reduces the fuel consumption per ton of glass produced. The melter is completely enclosed, unlike conventional glass-making furnaces. Feed requirements for the fossil fuel-heated ceramic melter vary. Waste glass, as an additive, may be used instead of the more expensive, high-purity additives typically used for glass making. The addition of waste glass buffers the changes in chemical composition of the feed material. Feed to the melter can be provided by pneumatic transport (dry), screw fed, or slurry fed systems. Another difference in Vortec's advanced vitrification process is that this process employs a proprietary cyclone melting system. Waste material is injected into a counter-rotating vortex combuster where incineration and melting occur. This system allows for a higher retention of volatile inorganics and lower particulate emissions.

Vortec is currently operating a 20 ton-per-day plant for the treatment of hazardous wastes. The plant can be used as a small-scale production facility or as a pilot plant, and the construction of larger-capacity plants is possible.

2.2.2 Alternative Vitrification Processes

As stated previously, fossil fuel-heated ceramic melters, joule-heated ceramic melters, and plasma arc torch units have all been found to be potentially viable vitrification processes. Joule-heated ceramic melting (JHCM) was the subject of a special study conducted for the Weldon Spring site by Battelle Pacific Northwest Laboratory (Koegler et al. 1989). The study results showed that the JHCM process is capable of producing a leach-resistant product with desirable structural properties. The plasma arc torch process uses electrical energy and produces a leach-resistant material with a significantly reduced volume. More detailed descriptions of both these vitrification processes are presented in Section 3 of the Phase I EAA (MKF and JEG 1992a).

3 DEVELOPMENT OF ALTERNATIVES

The following section presents the rationale used to develop the operational assumptions for individual components within an alternative and a brief summary of the alternatives evaluated in the feasibility study (FS) for the Weldon Spring chemical plant area.

3.1 Development of Alternatives

The results of previous technology evaluation studies were used to develop parameters and identify components of the alternatives addressed in the FS analysis of remedial action alternatives. It should be noted that operational details are presented to show that the respective alternatives are logical and can be implemented. The preliminary design concepts, costs, and schedules presented in the following discussions will be reevaluated during conceptual and final design. Both design phases will optimize the implementation of remedial action alternatives and reasonable modifications should be expected. Certain aspects of the various alternative components are relatively straightforward and may not require special studies or design considerations. Those areas that are more complex and will likely warrant special consideration are addressed below by component category.

It should be noted that reference to a particular manufactured brand of equipment does not constitute an endorsement of that manufacturer or convey an intent to rely specifically on this equipment for any work described in this document. Rather, these references are used solely for the purpose of describing equipment class, size, horsepower and capability for cost estimating and schedule development.

3.1.1 Removal

The majority of the chemical plant site source areas can be remediated using conventional construction equipment; the only exception is the raffinate pit sludge. A separate study, the *Raffinate Sludge Dredging and Dewatering Study* (MKES 1992a), concluded that dredging the sludges represents the optimal removal scenario based primarily on requirements for reducing emissions of dust particulates contaminated with thorium-230 and ease of materials handling. Dredging will inherently allow sludge removal to occur under several feet of water which will also reduce radon emissions.

To accurately estimate equipment and labor requirements for material removal and transportation requires a detailed and lengthy evaluation of the physical nature of the material to be removed. Appropriate equipment types and sizes are selected based on design criteria such as the material's physical characteristics, volume to be moved, degree of selectivity desired, required delivery rates, haul distances, weather considerations, road limitations, and operating schedules. Manpower and equipment operating requirements, such as the time to load, transport, unload, and return to the loading site, were estimated using haul cycle evaluation methods. Engineering calculations developed by the project served as the basis for these evaluation methods and the discussion in Section 4.2.2, thereby maximizing the use of existing information and minimizing any potential duplication of effort.

3.1.2 Physical Treatment

Approximately 165,600 cubic yards of the nearly one million cubic yards of waste materials consist of rubble and debris from the quarry and from chemical plant building dismantlement and waste areas. This material includes rock and concrete, metal, equipment, wood, and other typical construction debris. These types of wastes are not candidates for the primary treatment technologies under consideration, chemical solidification/stabilization and vitrification, since these materials are less likely to absorb contaminants. Physical treatment may be required, however, either to facilitate handling of these materials or to reduce them to an acceptable form for placement and disposal within an engineered cell. A number of studies have been performed to facilitate the optimization of processing these materials. The following list represents the more significant of these studies:

- Sizing of Building Materials and Structures (MKES 1992d).
- Metal Melting Technology (JEG 1992a).
- Decontamination Study (JEG 1992b).
- Size Reduction (JEG 1992c).

The largest percentage of these materials is made up of metal wastes. Management of metal waste will depend on plate thickness, size and dimensions, type of metal, and surface accessibility. These properties will determine the distribution of the metal wastes into one of the four following categories.

(1) The first category is made up of those materials such as structural members, I-beams, and rails where all surfaces are accessible making it feasible to employ practical decontamination methods such as hydrolasing.

(2) The second category consists of loose, miscellaneous metals which are amenable to shredding. Shredded materials could easily be handled, placed with soils, and incorporated into the fill within an engineered cell.

(3) The third category represents those materials where shredding and decontamination is not practical but the material is amenable to size reduction. Mechanical size reduction, i.e., hydraulic shears, cutting torches, etc., would be performed to the extent necessary to place these wastes within a lift (typically 12 inches) in the engineered cell.

(4) The fourth category is comprised of those materials whose sizes, dimensions, and/or metal types, render them outside the capabilities of the other three categories. These include large pieces of equipment or machinery that would be placed in a cell intact. The preferred scenario is one where these large pieces are placed intact and incorporated into the cell by utilizing a pourable grout to fill voids in and around the individual vessels, pieces of equipment, etc.

The disposal of other non-metal categories of debris is more straightforward. Rock and concrete, after being size reduced during removal, may be pulverized or shredded (rebar) to facilitate handling and placement. Wood and vegetation from clearing and grubbing activities will be chipped and hauled to the mulch pile.

Although interim storage of clear and grub and wood products is addressed in each alternative as a mulch pile located in the northern section of the site, composting of these materials is being considered. If composting is pursued as a storage option, wood volumes placed in the disposal cell would decrease as a result of decomposition of the organic materials.

The preliminary design concepts presented in this engineering evaluation include utilization of a volume reduction facility (VRF) to house primary physical treatment equipment. If subsequent optimization studies determine that a VRF is not required, sizing activities may be performed at certain storage areas.

3.1.3 Chemical Solidification/Stabilization

As discussed in Section 2.1, previous studies performed by Oak Ridge National Laboratory (ORNL) form the basis for the chemical solidification/stabilization (CSS) component. Actual raffinate sludge samples were tested, the results of which demonstrated the general feasibility of this technology (Gilliam and Francis 1989). Further studies, however, are currently underway to quantify the leachability of treated wastes and to optimize the formula for the amount of cement, fly ash, and any other additives which may be required.

These studies also include testing to evaluate product forms including a soil-like soil/cement mixture and a pourable monolithic grout. The soil-like material would be placed in the cell and compacted in lifts similar to the placement of soils. The pourable grout would be used to fill voids in and around large pieces of equipment and would be placed using forms or grout berms within the cell to completely encapsulate these types of materials. Other studies, such as the *Stabilization Fatal Flaw Analysis* (MKES 1992b), also support the applicability of CSS technology for Weldon Spring wastes.

3.1.4 Vitrification

Studies have also been performed using raffinate sludge samples to demonstrate the technical feasibility of vitrification technology (Section 2.2). These studies, performed by Battelle Pacific Northwest Laboratory (PNL), support the applicability of vitrification technologies to the Weldon Spring site wastes (Koegler et al. 1989). Other studies, such as the *Vitrification Fatal Flaw Analysis* (MKES 1992c), also support this conclusion. For optimization purposes, additional testing will be performed to define parameters such as operating temperature, fuel usage, retention time, etc.

For purposes of these studies, the fuel source for the vitrification melter is assumed to be natural gas. A preference for natural gas over other fuel sources such as fuel oil, coal, and electricity is based on factors such as availability, cost, and emissions. Compared to other fossil fuels, natural gas is also more attractive because of the capability for delivery via pipeline as opposed to over-the-road transport.

The preferred form of the vitrified product is fritted as opposed to monolithic. This product form is produced by immediately quenching the molten vitrified glass in water which results in a product ranging in diameter from ⅛ to ¼ inch. The fritted product will facilitate material handling and eliminate the time required for a monolith to cool prior to placement within the cell. The fritted product, however, is probably not compactable, and clean fines will need to be added to achieve compaction. In addition, this alternative does not afford the flexibility of a pourable grout to encapsulate large pieces of equipment. It may be desirable to add a portable pug mill to the vitrification alternative to generate a pourable grout, as necessary, to encapsulate these pieces of equipment within the cell.

3.1.5 On-Site Land Disposal

The on-site disposal options consider whether the treated wastes are the product of vitrification or CSS technology. Under the CSS alternative, it is proposed to combine the treated and untreated wastes into a single engineered cell designed to meet the performance requirements for radiological wastes under the Uranium Mill Tailings Radiation Control Act (UMTRCA) and hazardous wastes under the Resource Conservation and Recovery Act (RCRA). The cell may be above ground and equipped with a double liner/leachate collection and removal system (LCRS) and a typical UMTRA-type cover. Cell construction alternatives also include below ground excavation and clean fill perimeter dikes.

For the vitrification alternative, the waste may be segregated with the treated and untreated wastes placed in two separate cells. The cell for containment of the vitrified material would be below grade with a liner consisting of in-place soils (compacted clay). Synthetic liners and leachate collection/removal systems are not warranted given the expected superior performance of the vitrified product concerning leachability, durability, and the destruction of organic contaminants. The cell would be capped with a typical UMTRA-type cover. The untreated waste would be contained in an adjacent above-ground cell with a design very similar to the CSS alternative. The only exception is that a single liner with a leachate collection system will be used as opposed to the double-lined/LCRS used for the CSS alternative. The rationale for the single liner system relates to the fact that no hazardous waste would be placed in this cell. As an alternative, the vitrified and untreated wastes may be combined and placed within a single cell incorporating the design features of the untreated waste cell. This cell configuration may also include below ground excavation and clean fill perimeter dikes.

3.1.6 Transport to Off-Site Land Disposal Facility

Development of the transportation component of the off-site alternatives relied on information generated in the *Off-Site Transport and Disposal Options Study* (MKF and JEG 1992b). This study evaluated several alternatives including truck, rail, and barge transport of both bulk and containerized waste shipments. The results of this study show that rail transport is less expensive than both barge and truck transport to the potential off-site disposal locations. Rail transport also has advantages over truck transport in the areas of traffic safety and occurrence of accidents. For rail transport, containerized shipments are preferred to bulk transport due to ease of handling during transfers and due to the greater safety and integrity of the shipment in the event of an accident.

Rail transport for the off-site disposal alternative would require construction of a rail siding facility in the vicinity of the site. An area near Wentzville, Missouri, approximately 15 miles from the Weldon Spring site was identified as a representative location for the proposed rail siding. A Wentzville siding location was used as a basis for calculating costs and environmental impacts based on a reasonable haul distance from the Weldon Spring site to an area suitable for such a facility.

3.1.7 Off-Site Land Disposal

For the alternatives stipulating off-site land disposal, physical treatment operations similar to those described for on-site disposal would be required to produce waste materials that are suitable for placement within an engineered cell. In addition, volumetric considerations associated with the primary treatment technologies take on increased importance, since transportation and disposal costs are based on total waste volume. Therefore, vitrification is preferred over CSS technology for off-site disposal alternatives since vitrification results in a significant volume reduction (68%), whereas CSS results in a significant volume increase (32%). Assuming vitrification is selected as the treatment technology to be employed for the off-site alternatives, treatment should be performed on-site to take advantage of the reduced volume requiring off-site transportation.

3.2 Summary of Alternatives

The following discussion addresses the alternatives remaining under consideration for remedial action at the Weldon Spring site as a result of the FS screening process. The alternatives under consideration include no further action (1), chemical stabilization and on-site disposal (6A), vitrification and on-site disposal (7A), vitrification and off-site disposal at Clive, Utah (7B), and vitrification and off-site disposal at Richland, Washington (7C).

The primary components of each of the five remedial action alternatives under consideration are summarized below. The number assigned to each alternative is consistent with the numbering of alternatives in the site feasibility study prepared by Argonne National Laboratory (DOE 1992a).

3.2.1 Alternative 1 - No Further Action

- Quarry bulk wastes stored at the TSA.

- Quarry vegetation and chemical plant wood stored in mulch pile.

- Chemical plant building debris and rubble stored at the MSA. (Alternatively, concrete block and concrete may be stored in an expanded Ash Pond spoils pile.)

- Site and quarry water treatment plants operational.

- Contaminated soil, raffinate, and sediment remains in place.

- Contaminated soil from construction activities stored in the Ash Pond spoils pile.

- Surface water, groundwater, and air monitoring required.

- Containerized chemicals and materials stored in Building 434.

3.2.2 Alternative 6A - Removal, Chemical Stabilization, and On-site Disposal

- Contaminated soils and sediments and site preparation materials excavated and hauled to temporary storage.

- Building foundations and underground piping and sewers excavated and hauled to the MSA. (Alternatively, concrete may be stored in an expanded Ash Pond spoils pile.)

- Single, double-lined disposal cell constructed (combination cell).

- Containerized process chemicals transported to Oak Ridge for incineration. (Oak Ridge is currently only accepting liquid mixed wastes; an alternative would be on-site neutralization or stabilization for other materials stored in Building 434.)

- Raffinate sludge dredged and pumped to CSS plant feed hopper.

- Raffinate pit clay bottom excavated and hauled to the TSA, to the CSS feed hopper, or directly to the cell.

- Raffinate pit rubble excavated and hauled to the volume reduction facility and disposal cell. (Recent engineering studies have recommended the elimination of the volume reduction facility. Some further size reduction may be reuqired in the storage area prior to transfer to the disposal cell.)

- Raffinate sludge and solid material metered to pug mill and blended with cement and fly ash.

- Raffinate pit clay bottom material and quarry soils transferred from TSA to CSS facility.

- Soil-clay mixture blended with fly ash and cement in pug mill.

- CSS product hauled to and placed in on-site double-lined disposal cell.

- Contaminated soils and sediments excavated and/or retrieved from temporary storage and hauled to disposal cell for emplacement.

- Building rubble and debris retrieved from storage and transported to the volume reduction facility or to the disposal cell.

- Building rubble and debris sized reduced and hauled to disposal cell for emplacement. (Recent engineering studies have recommended the elimination of the volume reduction facility. Some further size reduction may be required in the storage area prior to transfer to the disposal cell.)

- Material transported to the disposal cell and spread, incorporated, and compacted in the cell.

- Temporary storage areas, haul road surfaces, volume reduction facility and water control structures, removed and contaminated material transported to the cell.

- Site water treatment plant and CSS facility dismantled and contaminated material hauled to disposal cell for emplacement.

- Disposal cell closure.

- Site regraded and revegetated.

- Long-term monitoring and maintenance implemented.

3.2.3 Alternative 7A - Removal, Vitrification, and On-site Disposal

- Contaminated soils and sediments and site preparation materials excavated and hauled to temporary storage.

- Building foundations and underground piping and sewers excavated and hauled to the MSA. (Alternatively, concrete block and concrete rubble may be stored in an expanded Ash Pond spoils pile.)

- Two-cell disposal facility constructed; one single-lined cell and one unlined cell (compacted clay bottom). (Alternatively, both treated and untreated waste may be placed within the same cell.)

- Containerized process chemicals transported to Oak Ridge for incineration. (Oak Ridge is currently only accepting liquid mixed wastes; an alternative would be vitrification for other materials stored in Building 434.)

- Raffinate sludge dredged, dewatered, and transported to treatment facility.

- Raffinate pit rubble excavated and hauled to volume reduction facility and disposal cell. (Recent engineering studies have recommended that the volume reduction facility be eliminated. Some further size reduction may be required in the storage area prior to transfer to the disposal cell.)

- Raffinate pit clay bottom hauled to TSA, to the vitrification plant feed hopper, or directly to the cell.

- Raffinate pit clay bottom material and quarry soils transferred from the TSA to vitrification treatment facility.

- Raffinate sludge mixed with clay bottom material or quarry soils at treatment facility, conveyed to melter, and vitrified.

- Clay soils conveyed to melter and vitrified.

- Vitrified material hauled to and placed in on-site unlined (compacted clay bottom) disposal cell. (Alternatively, the vitrified waste may be combined with the untreated waste in a single-lined cell.)

- Contaminated soils and sediments excavated or retrieved from storage and hauled to a single-lined disposal cell for emplacement.

- Building rubble and debris retrieved from storage and transported to the volume reduction facility or to the disposal cell.

- Building rubble and debris sized reduced and hauled to single-lined disposal cell for emplacement. (Recent engineering studies have recommended the elimination of the volume reduction facility. Some further size reduction may be required in the storage area prior to transfer to the disposal cell.)

- Material is transported to the cell and spread, incorporated, and compacted in the cell.

- Temporary storage areas, haul road surfaces, volume reduction facility and water control structures removed and transported along with untreated materials, to the single-lined cell.

- Site water treatment plant and vitrification facility dismantled and contaminated material hauled to disposal cell for emplacement.

- Disposal cell closure.

- Site regraded and revegetated.

- Long-term monitoring and maintenance.

3.2.4 Alternative 7B - Removal, Vitrification and Off-site Disposal at Clive, Utah

- Contaminated soils and sediments and site preparation materials excavated and hauled to staging areas.

- Building foundations and underground piping and sewers excavated and hauled to MSA. (Alternatively, concrete block and concrete rubble may be stored in an expanded Ash Pond spoils pile.)

- Building debris and rubble hauled from the MSA to volume reduction facility and size reduced. (Recent engineering studies have recommended the elimination of the volume reduction facility. Some further size reduction may be required at the storage area prior to off-site transport.)

- Containerized process chemicals transported to Oak Ridge for incineration. (Oak Ridge is currently accepting only liquid mixed waste; an alternative would be vitrification for other materials stored in Building 434.)

- Raffinate sludge dredged, dewatered, and transported to treatment facility.

- Raffinate pit rubble excavated and hauled to volume reduction facility and/or MSA.

- Raffinate pit clay bottom excavated and staged at TSA or hauled to the vitrification plant feed hopper or to the staging area.

- Raffinate pit clay bottom and quarry soils transferred from TSA to treatment facility.

- Raffinate sludge mixed with bottom material or quarry soils at treatment facility, conveyed to melter, and vitrified.

- Clay soils conveyed to melter and vitrified.

- Vitrified material placed in containers for off-site transport.

- Building debris and rubble and sized-reduced rubble placed in containers for off-site transport.

- Contaminated soils and sediments not slated for treatment excavated, transported to storage, loaded into containers, and hauled to the staging area for off-site transport.

- Containers loaded onto trucks and transported to railroad siding in Wentzville, Missouri.

- Containers loaded onto railroad flatcars and transported to Envirocare disposal facility in Clive, Utah.

- Material unloaded and placed into disposal cell; containers decontaminated and returned to the site by rail to be refilled.

- Temporary storage areas, haul road surfaces, volume reduction facility, and water control structures removed and contaminated material transported to staging areas or loaded directly into containers for shipment to Clive, Utah, for disposal.

- Water treatment plant and treatment facility dismantled and contaminated debris shipped to Clive, Utah, for disposal.

- Site regraded and revegetated.

3.2.5 Alternative 7C - Removal, Vitrification and Off-site Disposal at Richland, Washington

- Contaminated soils and sediments and site preparation materials excavated and hauled to staging areas.

- Building foundations and underground piping and sewers excavated and hauled to MSA. (Alternatively, concrete block and concrete rubble may be stored in an expanded Ash Pond spoils pile.)

- Building debris and rubble hauled from MSA to volume reduction facility and size reduced. (Recent engineering studies have recommended the elimination of the volume reduction facility. Some further size reduction may be required at the storage area prior to off-site transport.)

- Containerized process chemicals transported to Oak Ridge for incineration. (Oak Ridge is currently accepting only liquid mixed waste; an alternative is vitrification for other materials stored in Building 434.)

- Raffinate sludge dredged, dewatered, and transported to treatment facility.
- Raffinate pit rubble excavated and hauled to volume reduction facility and/or MSA.
- Raffinate clay bottom excavated and staged at TSA or hauled to the vitrification plant feed hopper or to the staging area.
- Raffinate pit bottom and quarry soils transferred from the TSA to the treatment facility.
- Raffinate sludge mixed with pit bottom material or quarry soils at treatment facility, conveyed to melter, and vitrified.
- Clay soils conveyed to melter and vitrified.
- Vitrified material placed in containers for off-site transport.
- Building debris and rubble and sized-reduced rubble placed in containers for off-site transport.
- Contaminated soils and sediments not slated for treatment excavated, transported to storage and loaded into containers, and hauled to the staging area for off-site transport.
- Containers loaded onto trucks and transported to railroad siding in Wentzville, Missouri.
- Containers loaded onto railroad flatcars and transported to DOE's Hanford disposal facility in Richland, Washington.
- Material unloaded and placed into disposal cell; containers decontaminated and returned to the site by rail to be refilled.
- Temporary storage areas, haul road surfaces, volume reduction facility, and water control structures removed and contaminated materials transported to staging

areas or loaded directly into containers for shipment to Richland, Washington, for disposal.

- Water treatment plant and vitrification treatment facility dismantled and contaminated debris shipped to Richland, Washington, for disposal.

- Site regraded and revegetated.

3.3 Off-Site Borrow Requirements

Table 3-1 is a summary of off-site borrow materials that may be required for the on-site disposal alternative. Materials will be used for construction of access roads, support facilities, disposal cell construction, and site restoration and grading. Borrow materials may be classified in the following general categories, including a description of specific application:

- Low Permeability Clay: Infiltration barrier, radon barrier, and engineered foundation.

- Structural Fill: Clean fill dike (disposal cell perimeter encapsulation).

- Common Fill: Site restoration and grading.

- Sand: Drain/filter and bedding layers for the cell cover, and drain/filter for leachate collection system.

- Gravel: Road/storage area surfacing and biointrusion layer of cell cover.

- Riprap: Drainage channel stabilization and cell side cover.

- Topsoil: Site restoration and cell cover.

TABLE 3-1 Summary of Off-Site Borrow Material Requirements (Quantities Are Preliminary Estimates)

	Volumes in Cubic Yards						
	Clay	Common Fill	Sand	Gravel	Riprap	Topsoil	
A. Off-site Disposal							
1) Raffinate Pits	1,650	117,267	0	18,858 *	0	50,000	
2) Excavation of Waste	0	129,391	0	17,800 *	0	0	
3) Vicinity Property	0	3,450	0	1,200 *	825	710	
4) Final Reclamation	0	157,009	0	0	0	37,000	
TOTAL	1,650	407,117	0	37,858 *	825	87,710	535,160
B. On-site Disposal - Chemical Stabilization/Solidification							
1) From Section A. Above	1,650	407,117	0	37,858 *	825	87,710	
2) Phase 1 disposal cell	172,066	77,066	25,000	46,999	38,333	4,778	
3) Phase 2 disposal cell	123,867	40,867	19,000	46,999	20,333	2,778	
4) Phase 3 disposal cell	172,067	77,067	25,000	47,002	38,334	4,778	
TOTAL	469,650	602,117	69,000	37,858 *	97,825	100,044	1,517,494
				141,000			
Cell Alone	468,000	195,000	69,000	141,000	97,000	12,334	982,334
C. On-site Disposal - Vitrification							
1) From Section A. above	1,650	407,117	0	37,858 *	825	87,710	
2) Phase 1 - single lined cell	172,000	72,000	25,500	26,500	36,000	4,500	
3) Phase 2 - single lined cell	172,000	72,000	25,500	26,500	36,000	4,500	
4) Vitrified Waste Cell	33,000	61,000	0	0	20,000	6,667	
TOTAL	378,650	612,117	51,000	37,858 *	92,825	103,377	1,328,827
				53,000			
Cell Alone	377,000	205,000	51,000	53,000	92,000	15,667	793,667

* Crushed Limestone

4 DESCRIPTION OF ALTERNATIVES

The following section presents an operational description of how each of the five alternatives developed in Section 3 would be implemented. The alternatives under consideration include:

- Alternative 1 - No Further Action.
- Alternative 6A - Removal, Chemical Solidification/Stabilization and On-site Disposal.
- Alternative 7A - Removal, Vitrification, and On-site Disposal.
- Alternative 7B - Removal, Vitrification, and Off-site Disposal at Clive, Utah.
- Alternative 7C - Removal, Vitrification, and Off-site Disposal at Richland, Washington.

The engineering concepts, equipment, and crews described in the following discussions are intended only to illustrate a practical basis for accomplishing site remediation. More definitive engineering concepts, equipment specifications, crew composition, and operating procedures will be developed based on the results of optimization analyses and on additional information developed prior to final design. The specific pieces of equipment described in these discussions are only intended to be representative of a practical means of accomplishing a specific task. Any reference to a specific manufacturer's product does not constitute an endorsement or reflect final selection of equipment type, size, and capacity.

4.1 Alternative 1 - No Further Action

Under Alternative 1, no further remedial activities will be undertaken other than the following interim response actions (IRA). This alternative is based on the assumption that these IRAs will be in effect as the baseline condition for the feasibility study.

1) The 96,800 cubic yards of quarry bulk waste is in storage at the temporary storage area (TSA).

   The 544,500-square-foot TSA will be an area with drainage, haul roads, and appurtenances. Runoff will be drained to a retention pond where it will be conveyed to a water treatment plant. The design life of the TSA, as currently conceptualized, is 10 years. However, this facility, supported by the water treatment plant, could perform its intended function for a considerably longer period.

2) Approximately 118,978 cubic yards of debris from dismantled buildings and structures are stored at the material staging area (MSA).

The MSA is being constructed in the northern portion of the site as part of a project interim response action. Thirty buildings at the Weldon Spring site will be dismantled after loose radioactively contaminated materials are removed to the extent feasible. Equipment and other material present in the buildings will also be removed.

The active life of the MSA, as currently conceptualized, is also projected to be 10 years. Materials to be stored in the MSA include structural metal, equipment, non-friable asbestos, and concrete rubble.

The MSA foundation is designed to ensure structural stability and to support the waste, cover material, and any equipment used on the area. The MSA will be located above the seasonal high-water table and will be underlain by recompacted, fine-grained soil to minimize infiltration and potential contaminant migration into the nearby environment during the active life of the facility. The MSA design also minimizes surface water runoff and run-on. A runoff collection system will contain runoff in an adjacent siltation pond prior to direct discharge to or treatment in the on-site water treatment plant (DOE 1991).

3) Approximately 5,800 cubic yards of contaminated soil are stored in the 4.1 acre Ash Pond spoils pile. As an alternative to the storage of concrete rubble in the MSA, this material may be placed within an expanded Ash Pond spoils pile. Drainage from this area is contained by the existing Ash Pond containment dikes and water control system.

4) The water treatment plant at the chemical plant area is operational.

The nominal flow rate capacity of the water treatment plant is 80 gallons per minute (gpm). However, to ensure efficient and continuous operation, the water treatment plant will be primarily operated at 55 gpm. Based on estimates developed for complete site remediation, the flow rate of 55 gpm would occur in years 3 to 5 of the remediation schedule. Under the no further action alternative, inflows will be much less than the maximum capacity requirements calculated for the complete remediation alternatives.

The site water treatment plant for the removal options will have a design life of 10 years and will consist of two treatment systems. An initial physiochemical system will treat wastewaters with low nitrate and low chloride contents which include the TSA runoff, MSA runoff, equipment decontamination wastewater, lavatory and shower wastewater, and water treatment plant recycle flows. The second system, a distillation system, is designed to treat water from Ash Pond and the raffinate pits. However, under the no further action alternative, Ash Pond and the raffinate pits will not be remediated, and consequently, the second system will not be constructed.

5) Under the no further action alternative, the containerized process chemicals and other materials stored in the Building 434 facility would remain in this controlled storage area.

Under the no further action alternative, contaminated soil, raffinate, and sediment will remain in place. However, the following activities will be continually performed at the site:

- Environmental monitoring.

    - groundwater.
    - surface water.
    - air.

- Maintenance.

    - MSA and TSA.
    - water treatment plant.
    - raffinate dikes.
    - pond dikes.
    - fences and other institutional controls.
    - remaining buildings.
    - road system.

- Operations.

  - MSA and TSA (run-on collection).
  - water treatment plant.
  - site security.

4.2 Alternative 6A — Removal, Chemical Stabilization, and On-site Disposal

This alternative is based upon the assumption that 6.5 hours of productive work will be accomplished during a standard 8-hour work period when hazardous materials are involved. Work in non-hazardous environments assumes that 7.5 working hours will be attainable during a standard 8-hour shift. Accordingly, all production rates are adjusted to an 8-hour shift basis. Operations are scheduled for a single shift, 5 days per week, 20 days per month, over a 9-month work year, allowing for a 3-month winter shutdown.

4.2.1 Site Preparation

Site preparation will include clearing and grubbing and placing fill and gravel throughout the chemical plant area to support the construction of the disposal cell, the treatment plant, on-site haul roads, and other support facilities.

Clearing and grubbing of the chemical plant site area includes clearing 24 acres of light and 13 acres of heavy vegetation. The light vegetation will be removed at a rate of approximately 0.5 acres per day by a 9-man crew using three 10-cubic-yard end dumps, a 3-cubic-yard loader, a D-6 dozer, a bush chipper, and a water truck during a 45-day work period. Heavy clearing and grubbing will be performed by a 12-man crew using the same basic equipment at a rate of approximately 0.4 acres per day during 30 work days. The chipped vegetation will be deposited in the mulch pile.

Clearing and grubbing of 14.6 acres at the raffinate pits for haul roads (3.6 ac) and work areas (11 ac) will be performed at a rate of approximately 0.5 acres per day by a 12-man crew using a 3-cubic-yard loader, a D-6 dozer, four 10-cubic-yard end dumps, 11 chippers, and a water truck over a 29-day work period. The chipped vegetation will be hauled to the mulch pile. A total of 28,700 cubic yards of vegetation cleared from those areas and from the quarry, together with 1,950 cubic yards of railroad ties, will be chipped and stored in the mulch pile.

Haul road construction includes clearing and grubbing the road alignment, placing 12 inches of fill from off-site borrow over a 30-foot road width, and applying 6 inches of gravel base on a geotextile which separates the fill material from the underlying contaminated material.

At the raffinate pit, the 12 inches (5,900 yd^3) of imported fill material for the road sub-base will be placed at a rate of 57 cubic yards per hour, assuming the borrow source will be within a 5-mile haul distance from the site. This work will be accomplished over a 12.9-day period by an 11-man crew using a 3-cubic-yard front-end loader, a water truck, a grader, a Raygo 400 compactor, and five 10-cubic-yard haul units.

Over a 4.3-day period, 3,500 cubic yards of delivered in-place gravel base will be placed over geotextile at a rate of 100 cubic yards per hour by a 9-man crew using a D-6 dozer, a Raygo 400 compactor (smooth wheel), a grader, a water wagon, and a flatbed truck.

Haul roads and storage area base for the chemical plant will require the placement of 23,400 cubic yards of imported fill and 9,400 cubic yards of gravel base. Completion of these operations, using the crews and production rates described above for the raffinate pit area, will require 51.3 work days and 11.8 work days, respectively.

Haul roads for Army vicinity properties 5 and 6 will require the placement of 2,400 cubic yards of imported fill and 1,200 cubic yards of gravel base in 3.4 and 2.1 work days, respectively. Clearing and grubbing of 3.0 acres will also be required.

Site preparation also includes the construction of five water control perimeter dikes requiring the placement of 37,900 cubic yards of embankment. Construction of the perimeter water control structures will include the clearing of 14 acres, removal of 3,850 cubic yards of top soil, excavation and embankment placement of 33,320 cubic yards of soil, and the hand compaction of an additional 4,580 cubic yards of soil.

The clearing operation will be performed at a rate of 0.75 acres per day by a 10-man crew using a 3-cubic-yard loader, two 10-cubic-yard end-dump trucks, a D-6 dozer, a water wagon, and a brush chipper during a 19-day work period.

Removal and storage of top soil will be performed at a rate of 73 cubic yards per hour with a 5-man crew using an elevating, self-loading scraper, a D-6 dozer, and a water truck. This operation will require 7 work days.

Soil excavation and embankment placement will be accomplished at a rate of 146 cubic yards per hour by a 9-man crew using 2 elevating, self-loading scrapers, a D-6 dozer, a Raygo 400 compactor, a water truck, a disk harrow, and a grader over a work period of 29 days.

Hand compaction placement will require a 6- or 7-man crew using a Case 580 backhoe, a water truck, and 2 or 3 hand compactors. Production will be at 14 and 21 cubic yards per hour over a period of 36 crew days.

4.2.2 Excavation and Transportation of Waste Materials

The focus of this task is the removal of sludges from the raffinate pits, the excavation of contaminated soils and sediments from the chemical plant area and vicinity properties, and the transport of contaminated material to the various treatment and storage facilities and the disposal cell. The crew descriptions and production rates included in the following subsections encompass the major on-site excavation and transportation operations. The various contaminated materials and their sources are described in Section 1.3.

During waste removal activities, sediment transport will be controlled by sediment control structures in addition to standard engineering practices. The control structures, which are addressed in detail in the *Chemical Plant Surface Water and Erosion Control Plan* (MKF and JEG 1991a), will be located within the site boundary and may include:

- A levee north of Frog Pond along site boundary to prevent run-on.
- A sediment control structure below Frog Pond.
- Two sediment control structures below the construction material staging area.
- A sediment control structure below Ash Pond.
- A sediment control structure south of Building 408.

4.2.2.1 Raffinate Pit Sludge. The raffinate sludge is a very fine-grained, gelatinous material consisting of 27% solids and 73% water. These physical characteristics lend themselves to a pumping operation as opposed to other, more conventional loading and hauling methods. The dredging procedure described below is based on the results of the *Raffinate Sludge Dredging and Dewatering Study* (MKES 1992a).

To remove the raffinate pit sludges and deliver this material to the treatment plant, a 60-tph cutting head dredge will be suspended in the ponded water and will direct the sludge to a 25-hp slurry pump mounted on the dredge. The sludge will then be pumped through a 4-inch pipe into surge tanks at the sludge processing area. Water will either be pumped or allowed to flow back into the pit to maintain dredge flotation. Flotation water replacement for material volume removal will be accomplished by pumping from raffinate pit 4, from site retention ponds, or from the site water treatment plant equalization basin. Additional equipment required will include one 1-ton welding truck, one 14-foot aluminum boat, and one 1,400-cfm compressor (250 hp). Dredging production rates will be as follows:

- Pit 1 - 17,574 tons @ 60 tph @ 6.5 hrs/day = 45.06 days or 9.0 weeks.
- Pit 2 - 17,574 tons @ 60 tph @ 6.5 hrs/day = 45.06 days or 9.0 weeks.
- Pit 3 - 130,896 tons @ 60 tph @ 6.5 hrs/day = 335.63 days or 67.1 weeks.
- Pit 4 - 56,156 tons @ 60 tph @ 6.5 hrs/day = 143.99 days or 28.8 weeks.

Assuming the above operating rates and a crew of 7, dredging the raffinate pit sludges will require approximately 114 work weeks. The four raffinate pits will be dredged in numerical order, with pit 4 receiving the water pumped from pits 1, 2, and 3 and providing replacement flotation water. Soils will be removed from the pits in the same order.

Fuel requirements include 8.5 gallons per week each for the welding truck and the aluminum boat. Electricity will be required to operate two 25-hp slurry pumps and one 100-hp dredge 32.5 hours per week.

Because the sludges will remain covered by water during removal, the dredging operation will not require dust control measures.

4.2.2.2 Soils and Sediments. Because of the physical nature of the soils and sediments, excavation and transportation of this material can be accomplished effectively and efficiently using standard construction/earth-moving equipment. Since standard earth-moving equipment has a high degree of mechanical reliability, with minimal downtime, major operational uncertainties are not anticipated. The selected excavation methods include:

- Backhoe loaders, operating from the top of the soil to be excavated, will place the soil into over-the-highway trucks for transportation to the disposal cell or to interim storage.

- Front shovel operating from the bottom of the excavation will place soil into over-the-highway trucks for transportation to the appropriate site.

- A front-end loader, operating from the storage area base or from the bottom of the excavated area, will remove soils and place the material into over-the-highway trucks for delivery to the appropriate location.

- Scrapers will be used to remove soils from large areas of relatively shallow depth and transport the material to the appropriate site.

The majority of the equipment will be diesel powered. A fueling station will be required to allow delivery to storage tanks from a clean (non-contaminated) zone. The excavation equipment will have access to the fueling station without decontamination. Fuel usage for equipment from each source area will be equivalent to standard construction fuel consumption rates for the stated operating times.

The removal and transportation scenarios developed for soils and sediments for each source area identified in Section 1.3 are described below. Material will be transported either to the treatment facility, TSA, Ash Pond spoils pile, or disposal cell as appropriate. Approximately 278,600 cubic yards of on-site and 23,600 cubic yards of off-site material are included in this category.

- **Ash Pond**. The 8,200 cubic yards of soil will be excavated from Ash Pond and hauled to the disposal cell at a rate of 70.8 cubic yards per hour by an 11-man crew assisted by four 10-cubic-yard end-dump trucks, a Hotsy steam cleaner, a CAT 235 front shovel, a D-6 dozer, a water truck (half time), a grader (half time), and two 4-inch pumps. Ash Pond soils and gravel base will be removed and hauled to the cell over a period of 21.5 work days. A 4,000-cubic-yard gravel working base will be installed in Ash Pond at a rate of 24 cubic yards per hour using the four haul trucks and a 3-cubic-yard front-end loader, as required, as the excavation progresses. Removal of the gravel base will follow excavation of the Ash Pond waste using the same removal crew and at the same production rate.

- **Frog Pond**. The 7,000 cubic yards of contaminated soil will be excavated and hauled to the disposal cell at a rate of 70.8 cubic yards per hour by an 11-man crew using four 10-cubic-yard end-dump trucks, a CAT 235 front shovel, a D-6 dozer, a water truck (half time), a grader (half time), and a 4-inch pump (quarter time). Frog Pond soils and gravel base will be removed and hauled to the disposal cell over a period of 13.8 work days. An 800-cubic-yard gravel working base will be placed at the bottom of Frog Pond at a rate of 24 cubic yards per hour using the four haul trucks and a 3-

cubic-yard front-end loader, as required, as the excavation progresses. Removal of the gravel base will follow excavation of the Frog Pond waste using the same crew and at the same production rate.

- **Busch Lakes 34, 35 and 36.** Remediation of the Busch Lakes will be coordinated with the Missouri Department of Conservation's (MDOC) routine drainage and sediment removal program. After the lakes have been drained by MDOC, hot spots of contamination (20,000 yd^3) will be removed and transported to at a transfer point adjacent to each lake using a 14-cubic-yard scraper. A 966E front-end loader will then load the material into five 10-cubic-yard end-dump trucks for transport. Haul trucks equipped with bed liners will be decontaminated before leaving the loading area and the disposal cell. With a 14-man crew and an excavation rate of 84.9 cubic yards per hour, 8,000 cubic yards of contaminated sediment can be removed from Lake 34 in 12 work days, 5,000 cubic yards from Lake 35 in 7.5 work days, and 7,000 cubic yards from Lake 36 in 10.5 work days. After the hot spots are removed, the transfer area at each lake will be reclaimed before returning the site to the MDOC.

- **North Dump.** Contaminated soil at the North Dump will be excavated using the same crew and equipment used for Frog Pond. At an excavation rate of 70.8 cubic yards per hour, the 7,600 cubic yards of soil will be removed and hauled to the Ash Pond spoils pile in 13.4 work days.

- **South Dump.** Contaminated soil and sediment at the South Dump will be excavated and hauled using the same personnel, equipment, and operating rates identified above for Frog Pond and the North Dump. At an operating rate of 70.8 cubic yards per hour, the 16,900 cubic yards of contaminated sediment will be excavated from South Dump and hauled to the disposal cell in 29.8 work days.

- **Raffinate Pits.** Following the removal of sludge and any residual surface water, the remaining 153,500 cubic yards of contaminated soils (clay bottom, embankment material, etc.) will be removed using conventional earth-moving equipment. The upper 1.2 feet (50,000 yd^3) of the pit bottom is anticipated to require treatment. This material will be hauled to and stockpiled at the TSA, or hauled directly to the treatment facility. Based on an operating rate of 68.8 cubic yards per hour, the excavation and haul time is estimated to be 90.8 work days or 18.2 work weeks for all four pits. This estimate assumes a 9.5-man crew using a CAT 235 front shovel, a D-6 dozer, four 10-cubic-yard end-dump trucks equipped with HEPA filters, and a half-time water truck.

Approximately 15,400 cubic yards of aggregate base will be placed on the bottom of the upper lift to stabilize the working surface. The end-dump trucks used for hauling will be loaded periodically on their return haul with aggregate from an on-site stockpile. Loading will be accomplished at an estimated rate of 24 cubic yards per hour. The aggregate base will be removed with the 2.5 feet of bottom material (103,500 yd^3) and hauled to the disposal cell over a 43.2-work week period, based on the same operating rate of 68.8 cubic yards per hour and excavation crew using a CAT 235 backhoe.

- **Other Site-Wide Surfaces.** Contaminated soils surrounding underground piping and sewer lines (20,000 yd^3) will be segregated by the CAT 215 backhoe used for pipe removal, and then reloaded and transported to the disposal cell or to the Ash Pond spoils pile by a 9-man crew using a 3-cubic-yard loader, four 10-cubic-yard end-dump trucks, a half-time grader, and a half-time water truck. At a rate of 56.3 cubic yards per hour, this operation will require 8.9 work weeks to complete.

  Contaminated soils beneath the building foundations and in open areas (65,400 yd^3), including the coal storage area, will be excavated and hauled to the Ash Pond spoils pile by a 10-man crew using 3 CAT 613 scrapers, a CAT 235 backhoe, a D-6 dozer, a water truck (half time), a grader (half time), a 4-inch pump (quarter time), and a 1-cubic-yard backhoe (quarter time) at a rate of 150 cubic yards per hour over a period of 10.9 work weeks.

- **Vicinity Properties.** Contaminated soils on Army properties 1, 2, 3 and Busch properties 3, 4, 5 will be excavated with a backhoe for optimum depth control and then picked up and trammed with a 3-cubic-yard front-end loader to a truck-loading area. The proposed excavation procedures at the truck-loading location and the use of truck bed liners will ensure that contaminants are not spread when the material is hauled to the disposal cell. The use of plywood sheets at the loading site will also minimize the accumulation of contaminated soil on the truck tires. Draping the liners over the outside of the beds will also prevent spillage during loading from coming in contact with the truck sides.

Excavation of the 1,160 cubic yards of contaminated soil in Army property 1 will be performed at a rate of 32.5 cubic yards per hour over a 4.5-work day period. A 13.25-man crew will use a CAT 235 backhoe, a 3-cubic-yard front-end loader, a water truck, three 10-cubic-yard end-dump trucks, one grader (quarter time), and a Hotsy steam cleaner.

Removal of the 630 cubic yards of waste at Army property 2 and Busch property 4 will require 3.8 work days at an operating rate of 20.4 cubic yards per hour. Soil removal will be performed by a 12-man crew using a CAT 235 backhoe, a 3-cubic-yard front-end loader, a water truck, two 10-cubic-yard end-dump trucks, and a Hotsy steam cleaner. Busch properties 3 and 5 are small, isolated areas containing an estimated 50 cubic yards of waste which will require approximately 2.5 crew days to remove.

Waste excavation at Army property 3 (approximately 60 yd^3) will be performed in 1.5 days at a rate of 5 cubic yards per hour. The 11-man crew will use a Bobcat loader, a 1-cubic-yard backhoe, a water truck, two 10-cubic-yard end-dump trucks, and a Hotsy steam cleaner.

Cleanup of Army properties 5 and 6 will require excavation of 1,700 cubic yards of contaminated soil and transportation to the disposal cell. This operation will be performed after the construction of adjacent access roads over a 4.5-work day period at a removal rate of 46.9 cubic yards per hour. Work will be accomplished by a 15-man crew using a CAT 235 backhoe, a water truck, five 10-cubic-yard end-dump trucks, and a diesel pump for diversion of minor water flow around the work area.

Remediation of Army properties 5 and 6 also involves the removal of contaminants that have migrated beyond the site boundaries as a result of runoff from the chemical plant site. Therefore, cleanup of these properties has been scheduled to begin after the reclamation of the chemical plant drainage area to prevent possible recontamination of cleaned areas.

4.2.2.3 Raffinate Pit Rubble. After excavation of contaminated soils from pit 4, approximately 500 cubic yards of rubble will be removed and transported to the disposal cell, or to the size reduction facility for processing. The debris will consist of concrete, tanks, barrels, pipe, wood, and structural elements. Some of the wood rubble may be composted to reduce volume prior to placement in the disposal cell. As discussed previously, composting alternatives will be based on the results of ongoing studies. Material size reduction will be performed at the volume reduction facility located near the MSA. Removal of rubble will be accomplished in 12.0 work days, based on a production rate of 5.2 cubic yards per hour by a 13.5-man crew. Required equipment includes a D-6 dozer (half time), a CAT 235 backhoe, two 10-cubic-yard end-dump trucks, and a water wagon (half time).

4.2.2.4 TSA Materials, Ash Pond Spoils Pile, and Mulch Pile. Material stockpiled in the TSA, Ash Pond spoils pile, and mulch pile will be reclaimed and hauled to the treatment facility, the volume reduction facility, or directly to the disposal cell. The 150,400 cubic yards of material to be stored at the TSA includes approximately 100,400 cubic yards of quarry bulk waste and 50,000 cubic yards of raffinate pit clay bottom. This volume includes 40,700 cubic yards of rubble that will be hauled to the volume reduction facility, 6,100 cubic yards of soil and sediment that will be placed directly in the disposal cell, and 100,000 cubic yards of soil and clay together with 3,600 cubic yards of water treatment plant residuals that will be transported to the treatment facility. The 5,800 cubic yards of soil stockpiled at the Ash Pond spoils pile and the 30,652 cubic yards of organic debris at the mulch pile will be transported directly to the disposal cell.

Approximately 40,700 cubic yards of debris stored in the TSA will require loading and transport to the volume reduction facility. This operation will be accomplished in 25.4 work weeks at a rate of 40 cubic yards per hour by a 4-man crew using a 3-cubic-yard front-end loader and two 10-cubic-yard end-dump trucks.

Contaminated material from the TSA, mulch pile and Ash Pond spoils pile will be loaded and transported to the disposal cell at a rate of 56.30 cubic yards per hour by an 8 man crew using a 3-cubic-yard front-end loader, a D-6 dozer, a water truck (half time), a grader (half time), and four 10-cubic-yard end-dump trucks over a 32.0-work-week period. The material will include 36,752 cubic yards of material from the TSA and the mulch pile; 5,800 cubic yards of contaminated soil stored in the Ash Pond spoils pile; an estimated 22,000 cubic yards of contaminated soil generated during waste removal operations during initial cell construction and stockpiled at the Ash Pond spoils pile; and 7,600 cubic yards from the North Dump, also to be stored in the Ash Pond spoils pile.

The 100,000 cubic yards of contaminated soils and sludges, along with the 3,600 cubic yards of water treatment plant residues, will be hauled to the treatment facility using a CAT 966E front-end loader with a 5-cubic-yard bucket at an average of 73 tons/hour (48 yd^3/hr) in 332 work shifts (6.5-hours-per-day basis). This operating rate is based on 12 cycles per hour, 55 minutes of production per hour, and a 95% bucket fill factor. Future planning will maximize the quantity of raffinate pit soil placed directly in the treatment plant feed system to reduce stockpiling and rehandled volumes.

The approximately 30,700 cubic yards of organic debris (including 1,950 yd^3 of chipped railroad ties) removed during site clearing and grubbing activities will be chipped and stockpiled at the mulch pile. A mobile unit could chip the material at an estimated rate of 4.5 tons per hour.

Clear and grub activities at the raffinate pits and chemical plant areas are scheduled to occur during 1993. Samples of the chipped clear and grub materials will be collected to determine concentrations of uranium, radium, and thorium. If contaminant concentrations exceed the cleanup criteria, the materials will be composted and eventually placed in the disposal cell. Based on UMTRA project experience, the maximum organic content of a disposal cell should not exceed 5%.

The mulch pile is tentatively sited at the northwest portion of the site (Figure 1-2) and would be actively managed to enhance the biological treatment process. Following is a list of organic materials which could be composted:

	Cubic Yards	Tons
Quarry clear and grub	5,300	3,340
Raffinate pits clear and grub	5,900	3,720
Chemical plant clear and grub	17,500	11,030
Chipped quarry railroad ties	1,200	650
Chipped chemical plant railroad ties	750	410
Paper	2	1
TOTAL	30,652	19,151

Analysis of cost and methods to support composting decisions are not yet completed. However, manpower and other costs would be an insignificant percentage of overall cleanup costs. Composting cost is low compared to incineration, and emission control and the resulting residuals are avoided.

4.2.2.5 MSA Material. Approximately 118,978 cubic yards of building debris and non-friable ACM in storage at the MSA will require loading and transport to the volume reduction facility or directly to the disposal cell. This operation will be accomplished over a 74.4-work-week period by a 4-man crew using a 3-cubic-yard front-end loader and two 10-cubic-yard end-dump trucks at a rate of 40 cubic yards per hour. Alternatively, approximately 58,814 cubic yards of concrete rubble may be stored within an expanded Ash Pond spoils pile.

Approximately 122,900 cubic yards of material consisting of quarry rubble (40,700 yd^3), MSA waste (75,800 yd^3), treatment plant closure materials (900 yd^3), raffinate pit rubble (500 yd^3), and used PPE (5,000 yd^3) will be loaded and transported directly from the MSA to the disposal cell or volume reduction facility at a rate of 40 cubic yards per hour by an 8.75-man crew using a 3-cubic-yard front-end loader, a D-6 dozer, a water truck (half time), a grader (quarter time) and three 10-cubic-yard end-dump trucks over a period of 76.8 work weeks. Recent engineering studies have recommended the elimination of the volume reduction facility.

4.2.2.6 ACM Storage Area. An estimated 9,827 cubic yards of ACM will be stored on-site. Approximately 4,716 cubic yards of the total consists of friable asbestos. The remainder consists of 5,111 cubic yards of non-friable asbestos-containing roofing, siding, and flooring which will be stored at the MSA. Prior to building demolition, ACM will be removed in accordance with the procedures specified in the individual work packages. All asbestos removal will be performed to ensure that no dust is generated and that all asbestos fibers are controlled. For example, pipes with ACM insulation will be wrapped, cut and transferred to a secondary staging area. The asbestos-containing insulation will then be stripped from the pipes within the fully enclosed staging area under negative air pressure. Gross removal of ACM will be performed within full enclosures under negative air pressure. The temporary on-site storage location after removal of Building 103 and final disposition of the ACM was the subject of a separate, uncompleted study. A temporary storage area for friable ACM has been constructed north of Buildings 403 and 404. The ACM is stored in sealed containers and will eventually be placed in the disposal cell.

Transport of the 4,716 cubic yards of friable asbestos to the disposal cell will be accomplished at a rate of 40 cubic yards per hour by an 8.25-man crew using two 10-cubic-yard end-dump trucks over a period of 3 work weeks.

4.2.2.7 Building 434. Approximately 400 drums of containerized chemicals, 5,000 cubic yards of contaminated PPE, (uncompacted) and 1,400 drums of radioactively contaminated materials that are not regulated but are above site release levels will be held in controlled, temporary storage in Building 434. The drums contain radioactively and nonradioactively contaminated soils, lubricating oils, PCB oils, solvents, paints, and other types of wastes. Characterization of these materials is not yet complete but will be completed before a disposal program is initiated. The preferred disposal option, as described in the FS, is for the drums containing liquid waste to be shipped to a licensed facility for incineration. The remaining 1,400 drums which primarily contain contaminated soil will be prepared and treated on site by neutralization or stabilization in accordance with appropriate regulatory requirements.

The PPE will be compacted as it is stored in Building 434 or, alternatively, will be transported to the volume reduction facility for size reduction prior to final disposition in the on-site disposal cell. Removal and transportation of this material will be accomplished over an extended period as equipment is available. The 4-man crew will require an estimated 1,300 hours to complete this task using one 10-cubic-yard truck and one drum loader (fork lift).

As stated, the drummed liquid wastes from Building 434 will be trucked to a suitable, licensed facility for incineration. Each truckload will contain 22 pallets of 4 drums each. Approximately 5% of the total exceed 2,000 pCi/g uranium-238 and will be classified as radioactive under 49 CFR 173. Special handling and special containers will be required for transport. The DOE has not formally approved any containers for the transport of liquid radioactive waste. Certification of a container or a variance from DOE Order 5480.3 will be necessary to ship the radioactively contaminated waste. In addition to these drummed liquid wastes, approximately 7,400 gallons of radioactively contaminated tributyl phosphate currently stored in tanks will also be transported to a licensed facility for incineration.

For purposes of this engineering evaluation, it was assumed that the K25 Incinerator at Oak Ridge would be available for treatment of the liquid wastes. The distance to Oak Ridge is approximately 500 miles. Transportation costs are estimated to be $1.65 per mile, with an additional $75 fee for loading or unloading times exceeding one hour. Based upon an 8-hour unloading time, a cost of $68 per ton has been used to estimate the transportation charges. The transporter will be a commercial, licensed hazardous materials transport company. Each load will be manifested, as necessary, and all trailers will be placarded according to the contents. Incineration costs have not been identified because waste characterization is not complete. An incineration cost of 50 cents per pound has been used, based upon engineering calculations developed by the project.

The transporter will be a commercial, licensed hazardous materials transport company. Each load will be manifested, as necessary, and all trailers will be placarded according to the contents.

If the Oak Ridge incinerator or an alternative facility is not a viable disposal option for liquid wastes, contingency alternatives will require more detailed evaluation. A contingency option may be to stabilize these materials in the on-site treatment facility or treat in the water treatment plant. No other specific disposal options have been identified for this relatively small quantity of waste. At present, other incinerators cannot accept radioactive material, and EPA regulations (40 CFR 268) prohibit land disposal without treatment to required standards.

4.2.2.8 Roads and Embankment Removal. Removal of the contaminated haul roads and the retention basins (30,830 yd^3) and transport to the disposal cell will be performed at a rate of 56.3 cubic yards per hour by a 13-man crew using a 3-cubic-yard front-end loader, a D-6 dozer, a water truck and four to six 10-cubic-yard end-dump trucks over a period of 13.7 work weeks.

Recovery of the 25,900 cubic yards of contaminated sediments and control dikes will be accomplished at a rate of 100 cubic yards/hour with a 12-man crew using a 3-cubic-yard front-end loader, a D-8 dozer, four 10-cubic-yard end-dump trucks, a grader, and a water truck. This operation will require 6.5 work weeks and will occur just prior to the cell closure.

4.2.2.9 Building Foundations and Underground Piping and Sewers. Demolition of 40,591 cubic yards of concrete slabs and pads will be performed over a 40.6 work-week period at a rate of 25 cubic yards per hour by a 10-man crew using a 235 backhoe, a hoe ram, 600-cfm compressor, a water truck, a 25-ton hydraulic crane, and a CAT 966 loader. After excavation, the contaminated concrete (52,768 yd^3 swelled volume) will be hauled to the MSA over a 19-work-week period at a rate of 70 cubic yards per hour by a 40-man crew using a 3-cubic-yard front-end loader and two 10-cubic-yard end-dump trucks. Alternatively, this material may be stored within an expanded Ash Pond spoils pile.

Approximately 64,240 lineal feet (1,309 yd^3) of underground pipe and sewer lines will be excavated and hauled to the MSA over a 101.7-work-week period at a rate of 15.79 lineal feet per hour. A 7- man crew will use a 1-cubic-yard backhoe, a 15- to 20-ton hydraulic crane, and a tractor-trailer.

Backfilling of the pipe trenches will require 102,501 cubic yards of clean excavation adjacent to the trench. This operation will be performed at a rate of 60 cubic yards per hour by a 9-man crew using a 1-cubic-yard backhoe and hand compactors over a 42.7-work-week period.

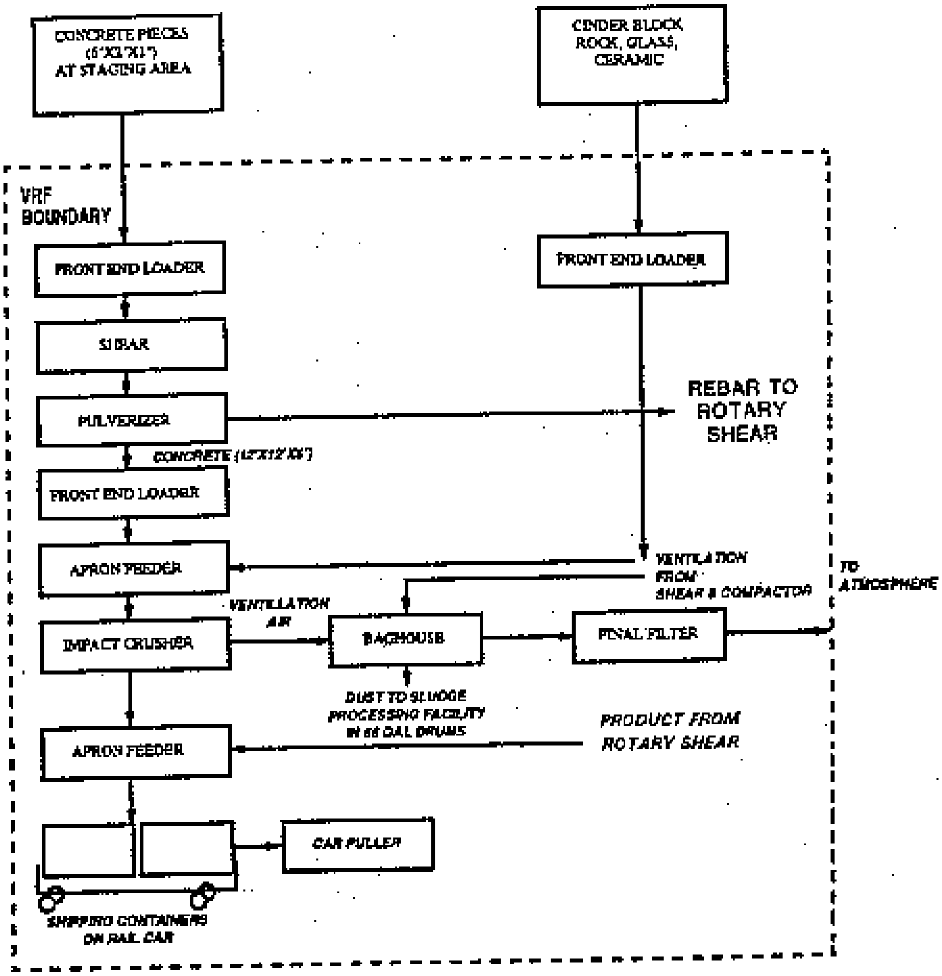
4.2.3 Volume Reduction

A volume reduction facility (VRF) will be constructed to manage materials requiring size reduction prior to placement in the disposal cell. The VRF will be located north of the MSA and will occupy a 9,000-square-foot area. The VRF area will be cleared and graded prior to construction. However, recent engineering studies have recommended the elimination of the volume reduction facility.

Table 4-1 lists the bulk waste quantities of candidate VRF feedstock (MKF and JEG 1991b). Figures 4-1 and 4-2 illustrate the proposed VRF process flows for these materials. These processes focus on crushing, shearing, and compacting which are widely used volume and size reduction techniques. An evaluation of the alternate volume reduction methods that are commercially available for processing Weldon Spring waste led to the conclusion that the bulk materials listed in Table 4-1 can be divided into four categories of waste (MKES 1992d). Following is a description of the four waste categories and the three major processing lines that will handle this material in the VRF (MKES 1992d). The materials to be size reduced will be delivered by 10-cubic-yard end-dump trucks to the VRF from the TSA, the MSA, and possibly the Ash Pond spoils pile.

TABLE 4-1 Quantities of Candidate Volume Reduction Feedstock

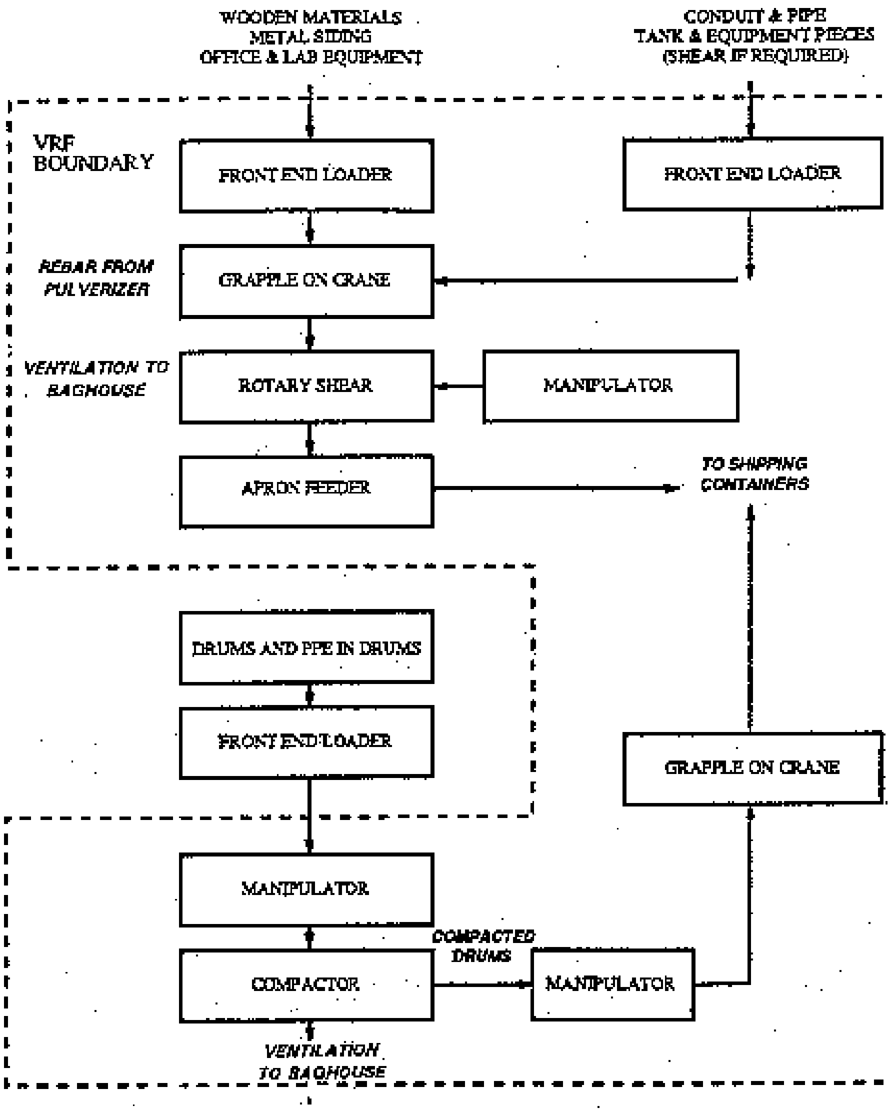
Material	Volume Yd³	Weight Tons
Quarry Bulk Metal	10,500	69,460
Quarry Bulk Rock/Concrete	30,200	61,910
Raffinate Pits Rubble	500	3,310
Treatment Facility (Closure)	900	3,890
Roofing, Siding, and Flooring	5,100	10,902
Friable Asbestos	4,700	2,929
Masonry Block	7,300	5,519
Slab Deck and Foundation	51,500	104,316
Debris	300	398
Conduit and Piping	2,400	3,925
HVAC Ductwork	100	333
Tanks	6,500	1,304
Miscellaneous Equipment	40,800	8,162
Underground Piping	1,300	1,734
Furniture & Solid Wood	2,300	924
Siding (Aluminum & Steel)	100	452
Structural Steel & RR Rails	1,100	7,645



VRF–PROCESS FLOWCHART

FIGURE 4-1

REPORT NO.:			EXHIBIT NO.:	A/PI/085/0591	
ORIGINATOR: BLG		DRAWN BY: GLN		DATE: 5/91	



VRF-PROCESS FLOWCHART

FIGURE 4-2

REPORT NO.			EXHIBIT NO.	A/PI/091/0591	
ORIGINATOR.	BLG	DRAWN BY:	GLN	DATE:	5/91

The first category of bulk waste is composed of materials which can be broken up by an impact crusher. This group of materials is shown in Table 4-2.

TABLE 4-2 Materials Reduced by Impact Crushing

Material		Volume Yd^3	Weight Tons
Quarry Bulk Rock/Concrete		30,200	61,910
Raffinate Pits Rubble		500	3,310
Treatment Facility (Closure)		900	3,890
Masonry Block		7,300	5,519
Slab Deck and Foundation		51,500	104,316
Underground Piping (non-metallic)		1,300	1,734
	TOTAL	91,700	180,679

The first processing line, using an impact crusher, will process concrete rubble, rock, cinder block, rock, glass, and ceramics. This material will be delivered to the processing line and handled using a front-end loader at the rate of 50 tons (about 40 yd^3) per hour. A shear will break up large pieces, and a pulverizer will break concrete away from rebar. The rebar will be hauled to the rotary shear, and the concrete will be fed to the impact crusher. The crushed product will be delivered to the loadout bin and subsequently reclaimed by front-end loader for transport to the on-site disposal cell. Dust collection equipment will be installed to remove the dust that is produced. This dust will be pulled into a baghouse and through a final filter by an induced draft fan.

The second category (Table 4-3) consists of materials which can be shredded or broken into small pieces by a rotating shear. Depending on the shredder feed stock, materials may be shredded into pieces as small as 1 inch (MKES 1992d).

TABLE 4-3 Materials Reduced by Rotary Shear

Material		Volume Yd³	Weight Tons
Debris		300	398
Conduit and Piping		2,400	3,925
HVAC Ductwork		100	333
Tanks		6,500	1,304
Furniture & Solid Wood		2,300	924
Siding (Aluminum & Steel)		100	452
	TOTAL	11,700	7,336

A rotary shear on the second processing line will cut and shred the feed materials producing fragments which have a reduced size and can be readily handled by conventional materials handling equipment. This line will process rebar, wood materials, metal siding, office and laboratory equipment, conduit, pipe, tank, and equipment pieces. These materials will be delivered by front-end loader at the rate of 40 tons per shift. A grapple on a bridge crane will feed materials to the rotary shear. A manipulator will position unwieldy materials for optimum shredding. The shredded material will then be delivered to the loadout bin. Ventilation and dust control will also be provided in this area.

The used personal protective equipment stored in drums comprises the third category. Over a 10-year period of operations, used PPE will total approximately 5,000 cubic yards (MKF and JEG 1991b). The 5,000 cubic yards of drummed PPE will be compacted on the third processing line. Drums will be delivered to the crusher in front-end loaders and placed in the compactor by a manipulator at the rate of 100 drums per shift. The manipulator will also remove the compacted drums from the compactor, and the grapple on the bridge crane will pick up the compacted drums and place them in the loadout bins. The compactor will also be equipped with dust control and ventilation systems.

A fourth category of waste is that for which treatment methods have not yet been determined. These materials and their quantities are shown in Table 4-4. Of the total shown, it is likely that an estimated 25,000 tons (14,500 yd³) of this material will be processed by the rotary shear.

TABLE 4-4 Materials with Volume Reduction Method to be Determined

Material		Volume Yd³	Weight Tons
Friable Asbestos		4,700	2,929
Roofing, Siding, and Flooring		5,100	10,902
Quarry Bulk Metal		10,500	69,460
Miscellaneous Equipment		40,800	8,162
Structural Steel and Railroad Rails		1,100	7,645
	TOTAL	62,200	99,098

In addition to the estimated 4,700 cubic yards of friable asbestos, approximately 5,100 cubic yards of roofing, siding, and flooring are also categorized as non-friable ACM. Large pieces of bulk metal, process equipment, structural steel, and railroad rails comprise the remaining materials in this category. The preferred method of disposing of these items may be to cut or shear them into conveniently sized pieces and to place them directly in the disposal cell. All members less than 3/8 inch thick will be sheared to facilitate placement in the disposal cell.

The total VRF feed volume is estimated to be 122,900 cubic yards. VRF operations will produce three primary product forms:

- The product of the impact crusher will be minus 2-inch concrete and rock pieces.

- The rotary shear product will be irregularly shaped pieces of less than 6 inches resulting from the shear's shredding and tearing action. The major dimension of these pieces will depend on the material being sheared; however, this material will be readily transportable by conventional material handling equipment. Debris, wood, and siding would experience minimal volume reduction, while conduit, piping, ductwork, tanks, and equipment pieces would have an estimated volume reduction between 10% and 47%.

- The product of the compactor will be flattened drums that can be handled with a manipulator and a grapple-equipped overhead crane. Volume reduction is estimated to be between 10% and 50%.

All process equipment and dust control equipment will reside within the VRF building. A preliminary equipment layout for the VRF is presented in Figure 4-3. The processed material will be deposited in concrete loading bins for retrieval with a front-end loader. The equipment required to operate the VRF is listed in Table 4-5.

TABLE 4-5 VRF Equipment

Item No.	Description	Price ($)	Unit
001,001A	Front-End Loader, 3.5-cu-yd bucket	125,000	each
002	Electrohydraulic Shear (50 Hp)	177,000	each
003	Electrohydraulic Pulverizer (100 Hp)	125,000	each
004,005	Electrohydraulic Manipulators (5 Hp)	30,000	each
006	Impact Crusher (200 Hp)	60,000	each
007	Rotary Shear (200 Hp)	275,000	each
007	Compactor (10 Hp)	23,000	each
008,009,010	Apron Feeders (5 Hp)	62,400	total
011	Bridge Crane, 5-ton capacity	60,000	each
012	Container Carrier Car or Loading Bins	360,000	each
014	Baghouse with I.D. Fan, 30,000 cfm	175,000	each
015	Final Filters, 30,000 cfm	50,000	each

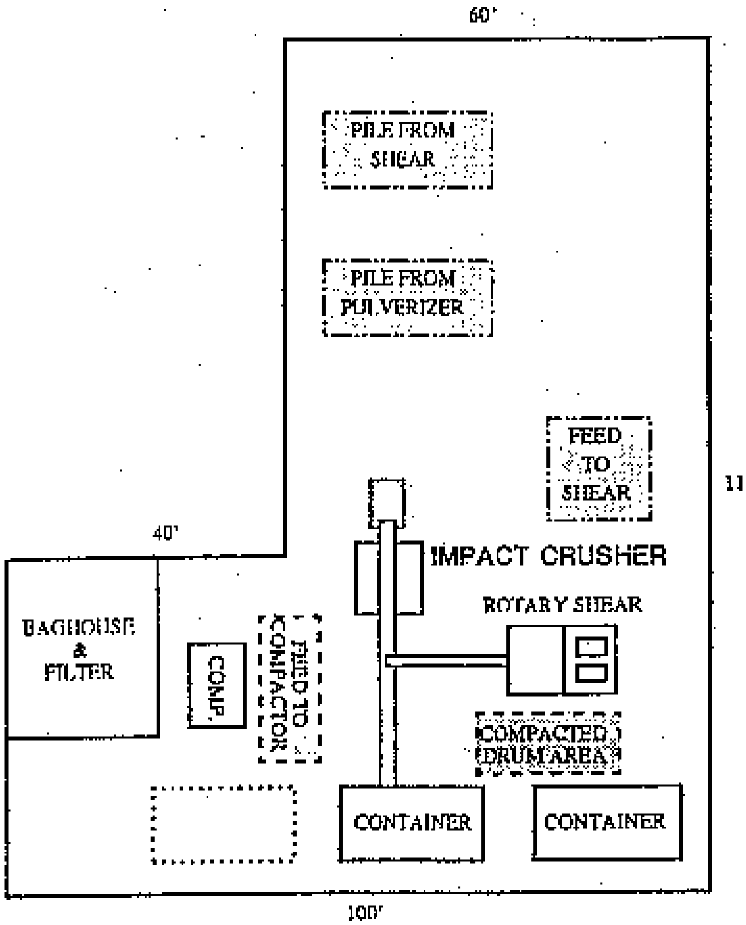
The principal means of dust control within the VRF building is a combined baghouse with induced draft fan, followed by a final filter to capture any particles that pass through the bag house filter bags. Dust collection hoods will be positioned over each major piece of equipment and each material transfer point. In addition, the building will have general ventilation hoods that will control any dust that escapes the process equipment hoods. The detailed design of the facility will include the option of using a dust suppressant if the ventilation system does not completely capture dust. Fog spray will be supplied to control dust during front-end loader operations and during retrieval from loading bins for on-site disposal. Material collected from the emission control devices will be transported to the on-site treatment facility.

Individual hearing protection will be used in the vicinity of the impact crusher. Use of individual respirators will be required in the vicinity of the shear, pulverizer, and impact crusher. Personnel entering the building will be attired in Level C personal protective equipment. Operation of the volume reduction facility will require an 8-man crew consisting

BUILDING AREA $= 60' \times 65' + 100' \times 50'$

$= 3{,}900 + 5{,}000$

$= 9{,}000\ ft^2$



VRF-PRELIMINARY LAYOUT

FIGURE 4-3

REPORT NO.		EXHIBIT NO.	A/PI/084/0591
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of a supervisor, equipment operators, a laborer, and maintenance personnel. The plant will operate over a 162 work week period.

4.2.4 Metals Decontamination

Certain metals may be decontaminated by conventional methods in association with VRF operations. This engineering evaluation assumes that metals decontamination will be an integral part of the VRF or will be supported directly by VRF operations. However, if a VRF is not constructed, sizing and decontamination activities may be performed within certain storage areas as required. The extent and location of decontamination activities are being studied. Decontamination of metals has not been included within the alternatives being considered.

Studies (JEG 1992b) have examined hydrolasing, liquid abrasive blasting, and metal melting decontamination technologies as alternatives for the treatment of structural steel, all categories of steel, and concrete slabs. Preliminary cost estimates were developed for these technologies and are listed in Table 4-6. The technologies are described in detail in Section 3 of the *Engineering Analysis of Remedial Action Alternatives, Phase I* (MKF and JEG 1992a).

TABLE 4-6 Cost Estimate of Decontamination

	HYDROLASING	LIQUID ABRASIVE BLASTING	METAL MELTING (STRUCTURAL STEEL)	METAL MELTING (ALL STEEL)
Capital	ND	$578,000	$5,174,000	$7,200,000
Labor	ND	$668,000	$4,785,000	$13,200,000
Operation & Maintenance	ND	$78,000	$478,000	$5,500,000
Operating Time	ND	3.1 yr	1.5 yr	3.5 yr
Present Worth Discount Rate @ 0%	ND	$1,324,000	$10,437,000	$25,900,000
Quantity of Material Decontaminated	ND	7,257 tons	7,257 tons	84,330 tons
Unit Cost	ND	$182/ton	$1,438/ton	$307/ton

ND = No data.

Implementation of decontamination technologies must meet surface contamination guidelines for release of surficially contaminated material for unrestricted use as provided in DOE Order 5400.5, *Radiation Protection of the Public and the Environment*. The order states that prior to being released, site materials shall be surveyed to determine whether both removable and total surface contamination (including contamination present on and under any coating) is greater than maximum specified levels (shown in Table 4-7). The order also states that contaminant removal complies with the requirements of the ALARA process.

TABLE 4-7 Surface Contamination Guidelines

	ALLOWABLE TOTAL RESIDUAL SURFACE CONTAMINATION (dpm/100 cm²)		
Radionuclides	Average	Maximum	Removable
Transuranics, I-125, I-129, Ra-226, Ac-227, Ra-228, Th-228, Th-230, Pa-231	Reserved	Reserved	Reserved
Th-Natural, Sr-90, I-126, I-131, I-133, Ra-223, Ra-224, U-232, Th-232	1,000	3,000	200
U-Natural, U-235, U-238 and associated decay product, alpha emitters	5,000	15,000	1,000
Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above	5,000	15,000	1,000

Source: DOE Order 5400.5, *Radiation Protection of the Public and the Environment*

(1) As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute measured by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

(2) Where surface contamination by both alpha- and beta-gamma-emitting radionuclides exist, the limits established for alpha- and beta-gamma-emitting radionuclides should apply independently.

(3) Measurements of average contamination should not be averaged over an area of more than 1 cubic meter. For objects of less surface area, the average should be derived for each such object.

(4) The average and maximum dose rates associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h and 1.0 mrad/h, respectively, at 1 centimeter.

(5) The maximum contamination level applies to an area of not more than 100 cubic meters.

(6) The amount of removable material per 100 square centimeters of surface area should be determined by wiping an area of that size with dry filter or soft absorbent paper, applying moderate pressure, and measuring the amount of radioactive material on the wiping with an appropriate instrument of known efficiency. When removable contamination on objects

TABLE 4-7 Surface Contamination Guidelines (Continued)

of surface area less than 100 square centimeters is determined, the activity per unit area should be based on the actual area and the entire surface should be wiped. It is not necessary to use wiping techniques to measure removable contamination levels if direct scan surveys indicate that the total residual surface contamination levels are within the limits for removable contamination.

(7) This category of radionuclides includes mixed fission products, including the Sr-90 which is present in them. It does not apply to Sr-90 which has been separated from the other fission products or mixtures where the Sr-90 has been enriched.

Possibly 5% of the structural steel in the contaminated site buildings (Table 4-8) could be released without decontamination. Separation of uncontaminated scrap metal from the contaminated material would require screening and hand sorting. Because of the added expense of screening and sorting, a partial off-site release of this material (without decontamination) would cost about 30% more than disposal in an on-site cell. These costs include demolition, hauling cell construction, placement in the cell, and scrap value. More importantly, the increased risks to workers handling potentially contaminated material must be weighed against the advantages of volume reduction and potential recycling. A maximum of 90% of the structural steel may be amenable to decontamination. Based upon 935 cubic yards (6,500 tons), decontamination by abrasive blasting would require about 2.75 years and cost approximately $1,183,000 excluding the costs of testing for release.

TABLE 4-8 Structural Steel Inventory of Contaminated Buildings

Building		Tons
101	Feed preparation and sampling plant	578
103	Digestion and denitration	875
104	Lime storage	22
105	TBP and ether extraction	601
106	Proof sampler	1
108	Nitric acid recovery	20
201	Green salt plant	1,287
301	Metals plant	1,300
403	Chemical pilot plant	200
406	Warehouse	27
407	Laboratory	282
417	Paint shop	13
431	Proof sampler	1

TABLE 4-8 Structural Steel Inventory of Contaminated Buildings (Continued)

	Building		Tons
432	Proof sampler		1
434	Storage		70
202	Green salt tank farm		88
404	Metallurgical plant		178
	Others		1,718
		TOTAL	7,262

4.2.5 Chemical Stabilization

This alternative is based on the assumption that the volumes and tonnages of waste media shown in Table 4-9 will require treatment by CSS technology as described in the feasibility study. This alternative focuses on treatment of the raffinate sludges, raffinate pit clay bottom, quarry soils, water treatment plant residues, and solid process chemicals. These materials will be processed separately and disposed of in an on-site disposal cell.

TABLE 4-9 Waste Media to be Treated by CSS Technology

Media	Volume (bank yd³)	Tonnage (short tons)	Moisture Content %	Dry Tons
Raffinate Sludge	220,000	222,200 [a]	73	60,000
Raffinate Pit Bottom Soil	50,000	76,000 [b]	20	60,800
Quarry Soils	50,000	76,000 [b]	20	60,800
Water Treatment Plant Residues	3,600	3,400 [c]	73	918
Solid Process Chemicals	28	23 [d]	73	6
TOTAL	323,628	377,623		182,524

[a] Density equals 1.01 tons/BCY
[b] Density equals 1.52 tons/BCY
[c] Density equals 0.94 tons/yd³
[d] Density equals 0.82 tons/yd³

Studies performed by Gilliam and Francis (1989) concluded that CSS treatment using a cement/fly ash mixture at a specified waste blend ratio in a pug mill mixer can solidify and stabilize the waste media sufficiently to meet project objectives. This conclusion is also supported by more recent studies performed by Waste Technologies Group (WTG 1992). Gilliam and Francis (1989) emphasized the CSS treatment of essentially undewatered raffinate. Therefore, this alternative also assumes that the raffinate sludge is not dewatered prior to reagent addition. Conditions for the proper use of the cement/fly ash mixture proposed by Gilliam and Francis will be extrapolated to allow appropriate solidification/stabilization of relatively drier raffinate pit bottom material and quarry soils. Treatment of the waste materials presented in Table 4-9 will produce the following quantity of CSS product:

Media	Volume (fill yd^3)	Tonnage (short tons)	Average[a] Density (calculated)
CSS Product	427,200	619,400	1.45 tons/BCY

(a) Density of the CSS grout and soil-cement materials ranged from 1.22 to 2.03 tons/BCY.

These values assume a 32% volume increase, as noted by Gilliam and Francis (1989), and account for the approximately 64% by weight increase due to reagent and water addition.

4.2.5.1 Site Preparation. The CSS plant will be located in the flat area along the southeast corner of Raffinate Pit 3 immediately north of the TSA. An area approximately 450 feet by 100 feet has been designated as the site of the CSS facility. This area will be cleared and graded prior to excavating plant foundations and installing utilities, which will occur concurrently with the delivery of mechanical equipment. Mechanical installation will follow the completion of the plant foundations. A 40-foot by 60-foot building will house the pug mill and control system devices. The surrounding area will be gravel surfaced to facilitate ease of access for maintaining delivery of reagent materials and transport of material to and from the plant. Equipment used for road construction and other site construction activities will be used to prepare the CSS plant location.

4.2.5.2 Plant Operations. Raffinate sludge will be introduced, as a dredged slurry, into the raffinate holding tank. A supernatant discharge line will return decanted water to the raffinate pits by gravity feed to minimize introduction of additional water to the CSS plant and to return excess water to the raffinate pit to assist in maintaining a sufficient water depth for dredging operations. Pumped raffinate will be metered to the pug mill at the rate of 73 tons per hour. Cement will simultaneously be introduced to a screw feeder at the rate of 17 tons per hour along with 26 tons per hour of fly ash. Thorough mixing of the reagents will occur during transportation by the screw conveyor, obviating the need for a separate blender. The reagents and raffinate will be fed into a pug mill, which has a design capacity of 140 tons per hour (15% above required throughput), producing approximately 120 tons per hour of a grout-like CSS product. A positive displacement pump will transfer the grout to a CSS waste hopper. The grout will be discharged into trucks for transport to the disposal facility. The grout is expected to achieve initial set in one day and final set within seven days.

Raffinate pit clay bottom and quarry soils will be transferred from the TSA to the CSS facility by a CAT 966E front-end loader with a 5-cubic-yard general purpose bucket. This size loader can easily provide the required 73 tons per hour of waste and can be used for other site activities. Twelve front-end loader cycles per hour are required. The following discussion presents a worst-case transport scenario in that it assumes that no material trucked from the raffinate pits is fed into the CSS plant. Future planning will optimize direct placement of the raffinate pit bottom soils in the plant feed hopper. Under this scenario, however, this material is transported to the TSA and subsequently hauled to the CSS plant with a 966E wheel front-end loader. This vehicle can transport about 6.4 tons per trip. Therefore, about 23,750 trips will be required to transport 76,000 tons of quarry soil and 76,000 tons of raffinate clay bottom material. The average one-way haul distance from the TSA to the CSS plant is about 600 feet. The continual availability of quarry soils at the TSA greatly enhances plant operation because quarry soils can be processed whenever raffinate sludge or raffinate pit clay bottom is unavailable.

Material will be directly dumped from the 966E loader or haul trucks into the plant feed system through a truck dump grizzly hopper. Clay and quarry soil will be transferred from the truck dump hopper onto an apron feeder. Large rocks (+12 inch) and cobbles (+1 inch) in the quarry soils will be removed by a grizzly and a vibrating screen, respectively, prior to CSS treatment. These oversized materials will be directly transported to the disposal cell and encased by a subsequent pour of CSS-generated grout. This alternative assumes that only minimal oversized waste exists. The plant production capacity is sized for zero percent removal of rocks and cobbles from the quarry soils. Oversized fragments are assumed not to exist within the raffinate sludge and raffinate pit bottom soil.

To ensure full hydration of the cement, water will be added at the rate of approximately 28 gallons per minute to the raffinate bottom and quarry soils. A water treatment feed stream or direct pumping from effluent ponds can maintain the 10% by weight hydration water demand.

To minimize dust generation, water will be introduced as a spray at the vibrating screen. Minus-1-inch soil and clay will then be screw-fed to the pug mill to be mixed with cement and fly ash. The CSS product will then be pumped to the CSS waste hopper to await truck transport. The resulting soil-cement mixture will be agitated within the hopper to prevent setting. Setting will not occur during the short haul to the disposal cell. The soil-like product is expected to be drier than the grout-like material produced from stabilized raffinate.

There is no plan to intentionally process metal debris or organic debris using CSS technology. However, the process feed material, particularly the quarry soils, will likely contain some quantitatively minor metal debris in the form of nails, bolts, etc. Organic material in the form of branches, twigs, and roots also is likely. Most of the stray metal and woody debris will be screened by the CSS plant grizzly (+12 inch) and vibrating screen (+1 inch); other visible large fragments will be hand-removed from the stockpile. The minor debris which passes the sizing screens will not adversely affect the CSS product. Wood-picking devices and a tramp metal magnet, for removal of iron fragments, can easily and quickly be retrofitted to the CSS facility, if necessary.

The plant will be equipped with a water washdown system. Washdowns will occur daily at the end of the shift. Approximately 5 gallons per minute of washwater used over a 1-hour period will be used to accomplish the washdown. Laborers' schedules will be designed to allow the one-hour washdown to be performed on a non-overtime basis. Washwater will be routed to sumps for recycling back to the CSS system. Sediment will be periodically removed from the sumps by small tractor-mounted backhoes and routed to the CSS plant soil feed system.

The CSS plant will use computer-assisted monitoring of the equipment to facilitate operations. Efficient use of scheduled uptime will be optimized by conducting routine preventive maintenance activities during lunch periods and after shift completion. Major repairs and replacements will also be performed during off hours. The significant amount of off-shift scheduled downtime will allow a 90% operating efficiency. Operator and maintenance personnel schedules will be adjusted to allow after-operating-shift activities to be performed on a non-overtime basis.

As described in this scenario, an estimated 3.5 general laborers will be required to operate the CSS facility. Automated and computerized feed control systems minimize the required labor force. Adequate industrial work experience will be required; however, specialized, formal training is not necessary. An estimated 2.5 maintenance personnel are required to repair and maintain the equipment. Journeyman-level machine repairman, millwright, electrician, and plumber specialties are required. One and one-half equivalent supervisors, 1.25 laboratory, and 1.5 administrative employees will also be required for plant operation. These employees will have adequate industrial experience. All employees involved with actual plant operation will be required to complete a 40-hour OSHA-approved training class (20 CFR 1910.120).

Dust mitigating measures will include several control methods. Feed material stored at the TSA (quarry soils and raffinate pit clay bottom material) will be covered by tarps and wetted prior to loading and transport to the CSS plant. The haul roads will be kept wet to prevent dust generation during transportation of the waste to the CSS plant and during delivery of cement and additives to the storage silos. To further minimize the generation of dust, grinding of oversized (+1 inch) material will not be performed. The plus-1-inch material will removed by a 12-inch grizzly at the truck dump and by a 1-inch wet screen. These fragments will be directly transported, along a wetted haul route, to the disposal cell for encapsulation by subsequent CSS grout placement. Water required to complete cementitious hydration reactions will be added as a spray at the vibrating screen, as previously discussed, to minimize dust generation. In addition, raffinate will be delivered and maintained in slurry form until reagents are added in the pug mill. The reagents will be delivered in sealed tankers and pneumatically transferred to baghouse-equipped silos. Reagent and product transport will also be by sealed screw conveyor.

An estimated 408 horsepower of electricity-driven motors, drawing about 306 kilowatts, will be required to operate the CSS plant. A CAT 966E wheel front-end loader will consume about 66 gallons of diesel per day during feeding of the quarry soil from the TSA to the CSS plant.

4.2.5.3 Plant Operating Schedule. The CSS operating schedule is based on the use of a 140-ton-per-hour design throughput pug mill to process all treatable media within 4.5 years (120 tons per hour). This schedule assumes operation at 6.5 hours per day, 20 days per month, and 9 months per year. The plant is sized to include an over-capacity production rate of 15% above the required throughput to allow for mechanical down time.

During the 4.5-year processing operation, an estimated 427,200 cubic yards of stabilized material will be hauled from the sludge stabilization holding bins to the disposal cell. This activity will be performed over a period of 159 work weeks at an average rate of 67.2 cubic yards per hour, based upon an 8-hour average. An 8-man crew will use five 10-cubic-yard haul trucks, a water truck (half time), a grader (quarter time), and a Case 580 loader (quarter time). Mechanical availability is assumed to be 90%.

After final design and construction of the CSS plant, a minimum of 3 to 4 months will be required to bring the system on line. During the start-up phase, the majority of the required adjustments to the equipment and processing technology will be identified. Equipment such as the screw conveyors, blenders, and pug mill will likely require the most adjustment.

4.2.5.4 Equipment Costs. The estimated capital cost of the equipment required for the CSS treatment process previously described is listed in Section 9.2.

The installed cost of this equipment is estimated to be approximately $3,100,000. With bench-scale and pilot-scale testing, estimated at $2,100,000, the total plant cost is estimated to be $5,200,000.

4.2.5.5 Mixture Requirements. The alternatives for the optimum cement/fly ash blend and reagent/raffinate mixing ratio will be narrowed down during pilot studies, and the final blending ratio will be determined during a full-scale run. Pretesting the raffinate sludges will determine the effects of particle size and chemical variation on the CSS process. The variation in water content in the raffinate and soils will likely present the greatest problem. Processing performance efficiency will be maximized during the 3- to 4-month initial start-up and operation of the system.

Gilliam and Francis (1989) recommended the addition of 40 wt.% Type II Portland cement and 60 wt.% ASTM Class F fly ash at a ratio of 0.6:1, dry-solids blend per unit of raffinate sludge. A 32% volume increase, as well as a 64% weight increase, was noted in the stabilized media. Formation of ettringite, a hydrated calcium aluminosulfate mineral, necessitates the use of the selected reagents and prevents the use of Type I Portland cement or ASTM Class C fly ash. The fly ash acts as a bulking agent and increases viscosity, preventing phase separation during setting, and also acts as a pozzolan (Conner 1990). Substituting fly ash for a portion of the cement results in a reduction in costs. However, this substitution also results in a larger volume and greater weight than with Portland cement alone.

Analysis of the reagent blend recommended by Gilliam and Francis (1989) reveals the initial CSS product has a very high water-to-cement ratio. Assuming 20% of the raffinate water would be unavailable for cementitious hydration reactions, a water-to-cement ratio of 2.2 is calculated. Normal water-to-cement ratios range from about 0.4 to 0.5. This suggests a significant amount of raffinate water could be removed without inhibiting complete cementitious mineral hydration. Approximately 30% moisture in the treatable media would be required, using the above reagent recipe, to fully hydrate the cement. Since about 10%, by weight, water will need to be added to allow full hydration of cement/fly ash/soil mixture, blending of undewatered raffinate and relatively dry soils may be optimal. For the purposes of this alternative, separate raffinate sludge and soil processing is presumed.

Based on the operating conditions and project duration information cited above, the following reagent consumption quantities and rates are estimated:

Total Cement	91,000 tons 112 tons per day 17 tons per hour
Total Fly ash	136,000 tons 170 tons per day 26 tons per hour
Total Water	15,000 tons 10,900 gallons per day during soil processing 28 gallons per minute during soil processing

A 5-day supply of cement (560 tons) and fly ash (850 tons) will be available on site to prevent operational shutdowns caused by periodically delayed reagent deliveries. Therefore, approximately 600 tons of cement and 900 tons of fly ash inventory will be maintained. Due to the low density of fly ash, approximately 60,000 cubic feet of storage silo volume is required.

Assuming that tanker trucks carry an average of 25 tons per trip, 5 tankers of cement and 7 tankers of fly ash will need to be delivered daily during operations. To minimize queuing of tankers, a pneumatic transfer system will be designed to empty a cement tanker within about 75 minutes and a fly ash tanker within about 45 minutes to supply the quantities of reagents necessary for a 7.5-productive-hour day. As Level C personal protective equipment is not required for transfer system operators, reagent delivery is assumed to be performed more efficiently than plant operation (7.5 productive hours versus 6.5 productive hours). Supplies of cement and fly ash are available from local suppliers within 25 to 100 miles of the Weldon Spring site.

Reagent delivery tanker trucks will enter and depart via the southern entrance to the Weldon Spring site. Trucks will drive around the northern end of raffinate pits 1 and 2 along about 400 feet of newly constructed road to the CSS facility. A tire washdown is presumed to be the maximum decontamination required prior to trucks departing the site. Maintaining a clean road system will eliminate the need for any additional decontamination efforts.

Chemically solidified/stabilized raffinate sludge will set within one day to form a monolithic concrete-like product having a density of approximately 1.22 tons per bank cubic yard. Relatively dry (20% moisture content) soil treated by the addition of 60% Class F fly ash and 40% Type II Portland cement, at a 0.6 to 1 reagent to waste blend with 10% added water to complete cementitious hydration reactions, would form a drier soil-cement material that could be placed into compacted lifts. This material would have a density of about 2.03 tons per bank cubic yard and could be effectively compacted using conventional compacting equipment.

The CSS-treated product must have a 28-day unconfined compressive strength (UCS) greater than 50 psi, which is necessary to support the lithostatic pressure of overlying waste to prevent disposal cell cover failure. The data of Gilliam and Francis (1989) demonstrate that CSS-treated raffinate exhibits several times the minimum compressive strength, with UCS values in the hundreds of psi. Even with the presence of potential set-inhibiting compounds in the Weldon Spring waste, continuous production of adequately strong CSS product can likely be maintained.

4.2.5.6 Testing Product. The CSS product for the Weldon Spring wastes will be required to pass TCLP criteria. Based on limited TCLP (WTG 1992) and RCRA characteristic testing results (BNI 1986), the raffinate sludge is not likely to fail toxicity characteristic regulatory levels in additional TCLP tests.

Stabilization testing performed by Waste Technologies Group (WTG 1992) and Gilliam and Francis (1989) have shown that fly ash and cement can successfully stabilize raffinate sludge and contaminated soil. Contaminant spiked sludge stabilized both in grout form (sludge and binder) and soil-like form (sludge, soil, and binder) passed TCLP tests for metals by an order of magnitude as well as selected organics (including 2-4 DNT stabilized at the highest concentration level found in quarry soils). WTG stabilized grout also provided ANS 16.1 leach indexes of 14 and 15, and unconfined compressive strengths of 125 to 335 psi.

WTG sludge testing has resulted in selection of appropriate flocculants to be used in conjunction with dredging the sludges. Additional stabilization testing has been performed on site and is also being planned to determine the impact of the flocculants and further optimize the stabilization treatment process mixture. More definitive characterization of the raffinate sludges will also continue.

During operations, the CSS material will be routinely sampled as it is produced. The sample will be compared to established testing criteria. Because placement of the unset CSS material in the cell is expected to be acceptable, this material will be taken to the disposal cell. If a sample should fail, the process system will be immediately modified to produce an acceptable product for subsequent batches. However, placed material represented by the failed sample will not be removed from the cell. The treatment process operating parameters will need to be optimized during pilot testing. The treated product produced during start-up testing will need to consistently pass the disposal criteria before full-scale operation can begin. The frequency of testing required to assure product quality will be established during start-up testing.

It is anticipated that leachate derived from the CSS-treated media will be strongly alkaline, with pH values of 9 to 12 likely. The alkaline conditions are caused by leachate reactions with free lime in the CSS product. The exothermic hydration reaction could cause leachate temperatures to reach 150°F (Mindess and Young 1980).

Although cement and fly ash have limited ion exchange capacities (Conner 1990) and limited adsorptive capacity, the deliberate addition of ion exchange materials to the CSS formulation is not presently planned. However, the alkaline pH conditions caused by the CSS reagents will induce precipitation of ferric, manganese, and aluminum hydroxides, which can adsorb heavy metals. Cement and fly ash also do not contain redox reactive constituents. However, addition of oxygenated water to CSS treated soils and raffinate pit clay bottom will result in an increase in the oxidation state of the CSS treated media. Consequently, the redox condition of the CSS-treated product will likely be governed by the ferric/ferrous couple.

4.2.5.7 Operational Uncertainties. The few operational uncertainties associated with this alternative are primarily related to the effectiveness of the assumed grout mixtures. As the mechanical components for the CSS process are well tested, operation of the plant equipment should be straightforward. It is presumed that an optimally designed operation will include equipment sized to complete each unit process with minimal potential for bottlenecking the overall operational throughput. Production constraints should be anticipated in the design and should result in minimal cost impacts; this translates into a policy of not allowing the productivity of the "high cost" equipment and unit processes to be limited by other activities. For example, the CSS plant operation should not be constrained by excavation capacity to the plant nor by removal of CSS product from the plant. It is more cost effective to have a single idling truck waiting for CSS grout to be produced than it is to shut down the entire CSS plant because transport trucks are unavailable to haul the grout to the disposal cell. Once an operation is optimally sized, changes in one unit process must be assessed relative to the potential impact on other activities. A well functioning operation is not routinely altered, particularly an operation that will run only a few years, as will the proposed CSS plant. During design, the CSS plant should be sized to complete activities within the scheduled time frame. Excavation, grout transport, and disposal cell construction equipment and fleet size should then be scaled to fit the CSS plant feed requirements and production capacities.

It is possible that CSS treatment plant throughput, as discussed in this submittal, could be increased; pug mills have design capacities of up to 200 tons per hour. Use of a larger system could decrease processing time to about 3 years. Working multiple shifts on a continuous basis could also reduce the processing duration. The throughput capacity of a CSS plant could be easily designed to process any reasonable proposed excavation rate; the duration of remedial activities will not be constrained by the CSS plant throughput limitations. It is anticipated that approximately 36 months will be required for bench-scale and pilot-scale testing, design, construction, and start-up.

Assumptions established for design and operation of a CSS plant must be verified by further bench- and pilot-scale testing. Pretreatment of the feed will also be investigated to optimize the effectiveness of the CSS process prior to full-scale plant design. System components will also be optimized through pilot or pre-operational testing. Variations in the reagent blend will be established to allow alteration of grout setting times with accelerators and inhibitors. Water content control and the use of bentonite and chemical reagents such as ion exchange resins will be defined to enhance contaminant immobilization.

4.2.6 On-Site Disposal

The on-site disposal cell will be designed to contain the current baseline estimate of approximately 1.25 million in-place (placed and/or compacted in the cell) cubic yards of wastes. The preconceptual design for this disposal cell will incorporate features used in disposal cells for uranium mill tailings (Uranium Mill Tailings Remedial Action Program) and chemically hazardous waste. This "combination" disposal cell will include a cover system with an infiltration/radon barrier and leachate collection and removal systems.

4.2.6.1 Waste Volumes. The wastes for disposal will consist of 470,000 cubic yards of chemically stabilized waste, 534,000 cubic yards of soil-like waste, and 246,000 cubic yards of rubble from the quarry excavation and chemical plant buildings demolition (a 10% contingency is included in each of the above in-place quantities). The total volume for all wastes is approximately 1,027,000 cubic yards (MKF and JEG 1991b). With the additional volume due to the addition of reagents during CSS treatment, the total in-place waste quantity will be 1,131,000 cubic yards. A contingency factor of 10% was assumed for sizing of the disposal cell, resulting in a design waste containment capacity of 1,250,000 cubic yards (rounded up). However, in order to ensure sufficient capacity to accommodate uncertainties as well as potential additional wastes from the quarry residuals, Femme Osage Slough, and the Southeast Drainage, the actual contingency factor may be higher (10%-50%).

Approximately 224,000 cubic yards of rubble will include various combinations of concrete, wood, metal, and other miscellaneous by-products, mainly from quarry excavation and chemical plant building demolition and dismantling operations. It is assumed that all building dismantling activities within the chemical plant area will occur prior to the construction of the cell, and that the resulting rubble will be stored at the MSA and undergo size reduction prior to transfer to the cell for placement. It is also assumed that the maximum dimension of rubble to be placed will be limited to 8 feet by 8 feet by 18 inches. Such material can easily be loaded and transported using ordinary on-site equipment and haul trucks. Placement of approximately 203,000 cubic yards of rubble will be required in conjunction with remediation of the chemical plant area operable unit. Approximately 21,000 cubic yards of material from the quarry and other waste sources will be subsequently placed in the cell.

The soil-like waste will result primarily from excavation of contaminated soil, chipping of organic materials, road surface reclamation, and the removal of water control structures from the chemical plant area and the quarry. Approximately 479,000 bank cubic yards will be produced from all sources. Quarry bulk waste and raffinate pit clay bottom material will be stored at the TSA, while other site wastes will be stored in the MSA, the Ash Pond spoils pile, the mulch pile or will be transported directly to the disposal cell. Approximately 377,000 cubic yards of this material from the chemical plant area operable unit will require placement in the cell.

4.2.6.2 Cell Design. A preconceptual layout of the combination disposal cell, developed in the siting study report (MKES 1991), is shown in Figure 4-4. A schematic section of a proposed combination cell as a prototype for the Weldon Spring site is shown in Figure 4-5. The wastes will be encapsulated in the cell by a double liner/leachate collection system.

The preconceptual design for the bottom liners and leachate collection system consists of (in descending order from the waste contact) a filter zone, an LCRS, an upper flexible membrane liner (FML), an second LCRS, and a bottom composite liner containing an FML and a compacted clay layer. The leachate collection system will be drained by perforated collection drain pipes to manholes or sumps immediately outside of the cell perimeter.

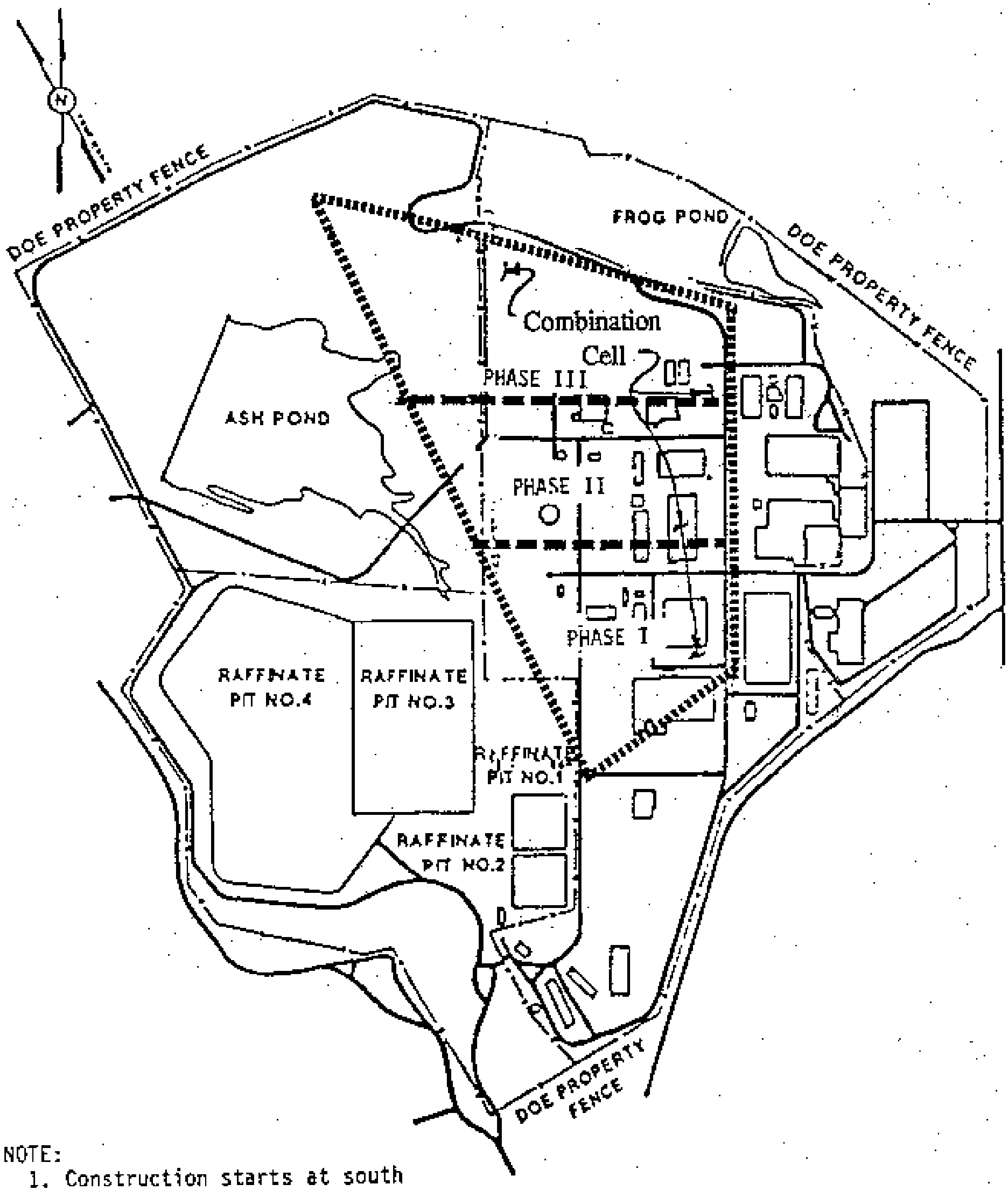
The preconceptual design for the cover on the top slopes of the cell embankment consists of (in ascending order from the waste contact) an infiltration/radon attenuation barrier, an FML, a filter-protected drain layer, a frost protection/bedding layer, and an erosion protection (riprap) layer to be choked with topsoil and fine-grained soil to support grass growth. Similarly, the side slope cover will consist of an infiltration/radon attenuation barrier, a frost-protection layer, an FML, a filter bedding layer, and an erosion protection (riprap) layer to be choked with topsoil and fine-grained soil to support grass growth. Alternative cell designs may include the use of a clean fill dike encapsulation system.

An estimate of the quantities required to construct each cell component is shown in Table 4-10. The quantities are based on a cell with a waste capacity of approximately 1.25 million cubic yards. All encapsulated soils and wastes, with the exception of CSS waste and grouted rubble, will be compacted.

The work described in the following paragraphs is dependent upon the rate that treated and untreated contaminated materials (wastes) are made available for placement in the cell. Approximately 1,007,000 cubic yards of wastes from the Weldon Spring site will be placed in approximately five years. The complete cell will be constructed in about 6.5 years. This extended construction schedule and certain sequencing requirements are the reasons for the low rates of material placement and the small equipment sizes used. The crew for each activity generally consists of the equipment operators, one foreman, and a helper.

Wind-blown particulates from the fine-grained materials involved in construction and waste placement will be controlled through dust suppression methods. Periodic spraying with water and/or dust suppressants will be used to control windblown matter while the cell is being constructed. When a section of the radon/infiltration barrier is completed, the surface will be sealed with a steel-wheeled roller, and if it is to be left unattended for a period of a month or more, a more permanent control measure, such as placing a flexible membrane over the fine-grained materials, may be used. Another means to minimize transport of contaminated particulates to the environment is by placing clean cover material on a selected side of the cell as the waste material is being placed and by encapsulating the cell phases as they are completed.

Radon gas will be emitted from the fine-grained waste material placed in the cell. Radioactive emissions in the air will be monitored during construction and operation of the disposal facility. If excessive radon gas levels are reached, as discussed in previous sections, engineering controls will be implemented to minimize public and worker exposure.



NOTE:
1. Construction starts at south

LEGEND:

TOE OF CELL

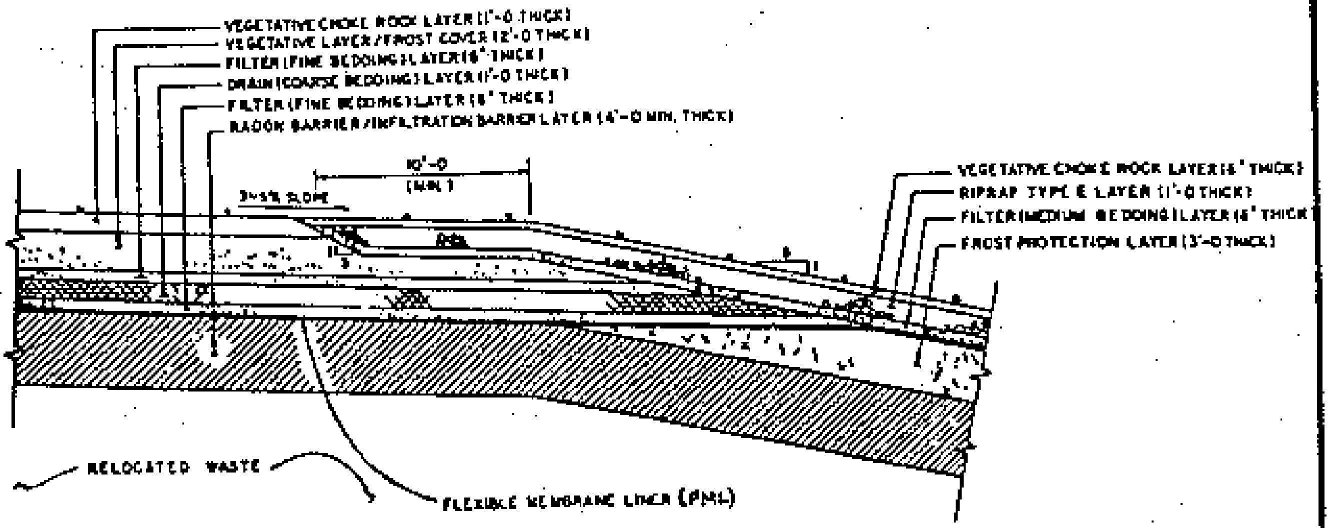
0 500' 1000'
SCALE

CONCEPTUAL LAYOUT OF DISPOSAL FACILITY

Combination Cell

FIGURE 4-4

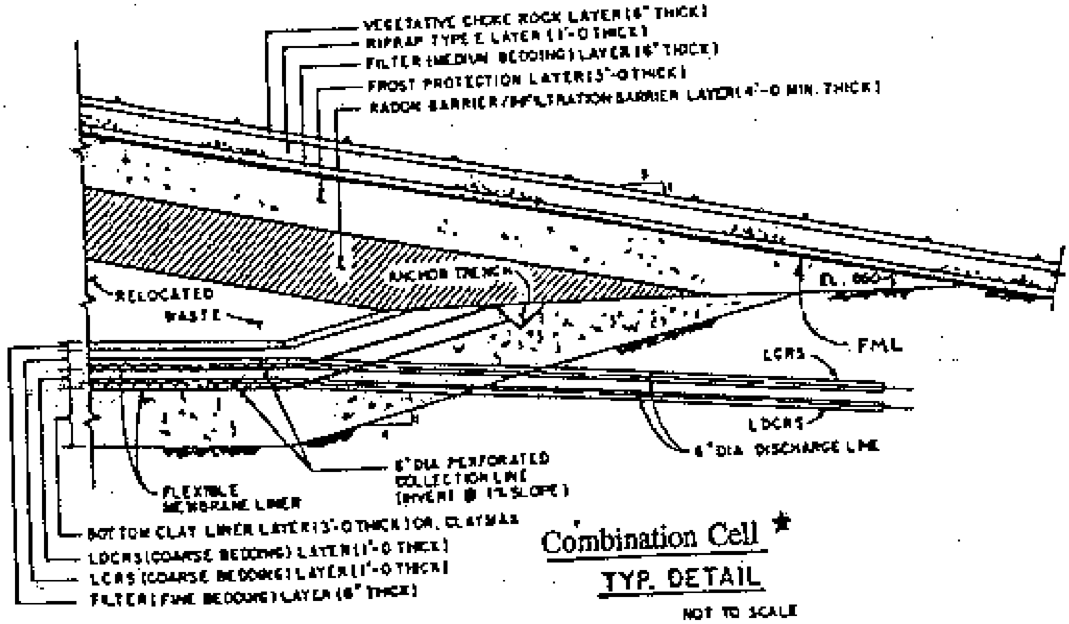
REPORT NO. 3840-TM-790-01	DRAWING NO.:	
ORIGINATOR: ECT	DRAWN BY: ECT	DATE: 4/22/91



Combination Cell or Single-Lined Cell Cover

TYP. DETAIL

NOT TO SCALE

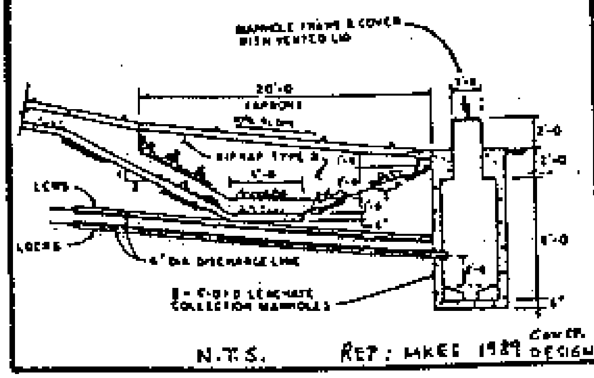


Combination Cell *

TYP. DETAIL

NOT TO SCALE

* ALSO APPLICABLE TO A SINGLE-LINED CELL IF THE LCRS IS DELETED.



TYPICAL CELL COVER AND LINER DETAILS		
Combination Cell or Single-Lined Cell		
FIGURE 4-5		
REPORT NO. 3840-TM-790-01		DRAWING NO.
ORIGINATOR ECT	DRAWN BY ECT	DATE 4/15/91

TABLE 4-10 Estimated Quantities for Various Earthwork Components for Combination Cell

1. Wastes to be relocated (Bank Volume)	Soil-like Waste	479,000	yd^3
	CSS Waste	324,000	yd^3
	Rubble	224,000	yd^3
	Total	1,027,000	yd^3
2. Wastes Placed in Cell (including 10% contingency factor)	Soil-like Waste	534,000	yd^3
	CSS Waste	470,000	yd^3
	Rubble	246,000	yd^3
	Total	1,250,000	yd^3
3. Cell Capacity	Combination Cell	1,250,000	yd^3
4. Foundation	Area	200,000	yd^2
	Excavation	150,000	yd^3
	Fill	150,000	yd^3
	3-foot Clay Liner	200,000	yd^3
	FML	200,000	yd^2
	1-foot LCRS	67,000	yd^3
	FML	200,000	yd^2
	1-foot LCRS	67,000	yd^3
	6-inch Filter	33,000	yd^3
	6-inch Dia. Pipe	18,400	lineal ft
	126-ft^3 Concrete Sump	40	Unit
5. Top Slope	4-foot Clay Cover	27,000	yd^3
	FML	20,000	yd^2
	6-inch Filter	3,000	yd^3
	1-foot Drain	7,000	yd^3
	6-inch Filter	3,000	yd^3
	2-foot Frost Protection Layer	14,000	yd^3
	1-foot Choke Rock Layer	7,000	yd^3
6. Side Slope	4-foot Clay Cover	241,000	yd^3
	3-foot Frost Protection Layer	181,000	yd^3
	FML	181,000	yd^2
	6-inch Filter	30,000	yd^3
	1-foot Riprap	60,000	yd^3
	6-inch Choke Rock	30,000	yd^3
7. Total Cell Cover Area		201,000	yd^2

4.2.6.3 Construction Sequencing. The disposal facility will be constructed in three phases, with two phases periodically overlapping. The area of construction for each phase will be approximately one-third of the cell area, divided equally in the longitudinal direction from south to north.

At the current projected rate of waste placement, each construction phase will last approximately three consecutive construction seasons with a 6.5-year period required for construction of the entire cell. Figure 4–4 illustrates the preconceptual disposal cell design. The first phase of cell construction will start along the southern edge (the shortest side) and proceed in a northerly direction to approximately one-third of the length of the cell. The second phase will start where the first phase was terminated and occupy the middle one-third portion of the cell. The Phase 3 area will occupy the remaining one-third of the cell, i.e., the northern portion.

Construction activities will start with foundation grading to an estimated 6 feet below ground surface, and construction of the composite liner and double LCRS in the Phase 1 area (Figure 4-4). After these activities are completed, placement of treated waste material within the Phase 1 area will begin. At this time, foundation grading and construction of the double LCRS in the Phase 2 area will also begin. Waste placement in the Phase 1 area will be topped off to the maximum designed cell height (74 feet minus cover thickness) before Phase 2 waste placement begins. Construction activities for Phase 3 will begin when the Phase 1 wastes are enclosed within the radon barrier. The purpose of this construction sequencing methodology is to limit the disturbed cell area to only two-thirds of the entire cell at any time. The use of this methodology will allow less exposure of the wastes to the environment and less rainfall runoff for retention pond collection and possible water treatment prior to release to the environment. Separation between the phases will be assured through the construction of berms between the waste placement phase and new cell construction phase.

Final accommodation for the actual waste volume will be made in the Phase 3 area by adjusting the northern cell slope, by varying the cell height, or by a combination of both. The cell footprint shown on Figure 4-4 will provide a waste capacity of 1,500,000 cubic yards (20% in excess of design requirements). Phases 1 and 2 should be constructed to this general configuration to provide maximum opportunity to adjust the cell into the MSA to accommodate an increased waste volume.

Access ramps for transporting materials to higher elevations of the cell during construction/operation will be constructed on both the western and eastern sides as cell construction proceeds to the north for each phase. A 10% maximum grade is assumed.

Construction operations for each phase will generally be performed in the following sequence:

1. Clearing and grubbing of cell areas, removal of underground piping and foundations, excavation of contaminated soils, and backfilling of deep excavations.

2. Final grading of subgrade.

3. Placement of 3-foot-thick clay layer.

4. Construction of LCRS.

5. Placement of a 4-foot-thick clean clay layer radon barrier (20-foot horizontal width) cover material at 5 to 1 (horizontal to vertical) slope in applicable areas to form a berm-like barrier for containment of relocated wastes. The clay layer construction will be kept slightly ahead (higher) of the waste placement such that the cover surface will always remain clean as all waste material placed adjacent to and within the cover perimeter will be sloped to drain towards the middle of the cell area, therefore, preventing possible contamination of the placed cover.

6. Placement of soil-like contaminated material on the interior side of the placed cover in a minimum 20-foot-wide zone, thereby forming a perimeter zone (berm) adjacent to the cell cover. The 20-foot-wide zone is adjustable depending on the actual availability of various wastes during construction.

7. Placement of rubble from the MSA, TSA, or the volume reduction facility in the cell area inside the outer perimeter berm of soil-like wastes.

8. Placement of CSS grout-like material on the rubble surface within the bermed area. The grout-like material will enter and fill the void spaces within and between the rubble.

9. Placement of CSS soil-cement material and soil-like material across the final surface of the grout-rubble fill.

10. Construction of remaining cover over side slope and full cover over top slope.

11. Place sod or seed completed section of cover.

12. Proceed with waste placement of subsequent phase in sequence as described above.

4.2.6.4 Cell Construction. Initial cell construction activities will include excavating approximately 150,000 cubic yards of material and placing 150,000 cubic yards of fill to grade the existing ground surface in the cell footprint to the finished subgrade elevation. The excavation and fill will be accomplished at a rate of 500 cubic yards per hour by a crew of 12 using two scrapers, a Raygo 600 compactor, a D-9 dozer, a D-8 dozer, a 4-inch pump (quarter time), a grader, a water truck (half time), a disk harrow, and a 1-cubic-yard backhoe (quarter time). This operation will require 37.5 work days to complete. Excavation of up to 6 feet is anticipated.

The next activity to be performed is to scarify and compact the finished subgrade (200,000 yd^2) prior to placement of the composite liner. This activity will be accomplished at a rate of 2,500 square yards per hour by a crew of 5 using a crawler tractor with a disk harrow and a Raygo 400 compactor. A water truck will be used to add water to achieve the specified moisture content and to control dust. Ten crew days will be required to complete the foundation preparation.

A 3–foot–thick clay liner totaling 200,000 cubic yards will be constructed as part of the composite liner for the cell. This material will be delivered from an off-site borrow area (within 5 miles) and placed at a rate of 80 cubic yards per hour by a 17-man crew using nine 10–cubic-yard end–dump highway haul trucks, a 988 loader, two D-6 dozers, a Raygo 400 compactor, a disk harrow, a 4-inch pump (quarter time), a grader to fine grade and maintain haul roads, and a water wagon to maintain specified compaction moisture content and to control dust. This operation will be performed over a period of 313 work days.

Approximately 200,000 square yards of FML will be placed over the clay layer by a crew of 8 using a tractor to unroll the material. Seams will be bonded by the placement crew and tested to assure that they meet quality control requirements. Placement will be continuous over one-third of the cell foundation at a rate of 20,000 square feet per day. Installation of the FML will require 90 work days.

A 1–foot–thick LCRS layer will then be placed. It is assumed that 67,000 cubic yards of gravelly, drain–type material will be purchased from a commercial source FOB job site. The material will be placed at a rate of 33 cubic yards per hour by a crew of 6 with a 2–cubic-yard loader, a smooth-drum vibrating roller, a grader, a water truck, and a 4-inch pump (quarter time). Embedded in this layer will be a network of 6–inch-diameter perforated high density polyethylene (HDPE) pipes to collect and direct leachate to sumps or manholes located immediately outside the toe of the cell. This network will be placed concurrently with the gravel placement by a crew of 6 at a rate of 50 feet per hour over a period of 23 work days. Gravel installation will require 254 crew days. Approximately 9,200 feet of pipe will be required.

The upper and lower LCRSs will each have 20 collection sumps or manholes for a total of 40. Installation of these elements will be performed by a crew of 6 using a Cat 235 backhoe, a flatbed truck, and hand compactors (half time). Installation is estimated at 13 crew hours per sump or manhole over a period of 70 crew days.

Another 200,000 square yards of FML will be placed over the lower LCRS layer, followed by the 67,000-cubic-yard, 1-foot-thick, leachate collection layer and 9,200 feet of HDPE pipe, overlain by a of 6-inch-thick layer filter sand material (33,000 yd^3). Construction will be the same as described above and will require the same type and number of equipment components and manpower to accomplish the work. Installation of the FML and the gravel with the collection pipe will be completed in 90 and 254 crew days, respectively. Filter sand will be delivered to the placement site and placed at a rate of 25 cubic yards per hour by a 6-man crew using a D-6 dozer, a 2-cubic-yard loader, a Raygo 400 smooth-drum compactor, a water truck, and a 4-inch pump over a period of 165 crew days.

Four basic forms of waste will be placed in the disposal cell: soil-like material, CSS grout-like material, CSS soil-cement material, and rubble. The soil-like material will be placed first, around the perimeter of the cell, to contain the CSS grout or soil-cement material and rubble.

The soil-like material will be delivered to the cell at various rates, depending upon the material source. The following summary provides the volume by major source area of soil-like material and the estimated delivery rate, as described in Sections 4.2.2.2, 4.2.2.4, and 4.2.2.8, for excavation and transportation of waste materials.

Source	Volume (yd^3)	Productive Rate (yd^3/hr)
TSA, Ash Pond Spoils Pile and Mulch Pile	72,200	56.3
Site Ponds and Dumps	36,900	70.8
Site Surface Areas	50,400	150
Underground Pipe	13,000	56.3
Raffinate Pit Bottom	118,900	68.8
Road Surface Reclamation	30,830	56.3
Water Control Removal	25,900	100
Busch Lakes	20,000	84.9

Rubble will be delivered at a rate of 40 cubic yards per hour. The rubble and soil-like material (203,000 yd^3 and 377,000 yd^3, respectively) will be either spread or spread and compacted by a 9-man crew using a D-6 dozer, a Cat 12 grader, a disk harrow, a water truck, and a Raygo 400 compactor over the 45 months of active waste placement in the cell. This crew will handle an average waste delivery of 100 cubic yards per hour, on a 6.5-hour productive work-day basis. The soil-like material will be placed along the perimeter of the cell and on the foundation and top of the cell to surround the rubble and CSS-grouted zone.

The 427,200 cubic yards of CSS grout-like material will be hauled from the CSS batch plant and delivered to the cell at an average rate of 67.2 cubic yards an hour on an 8-hour basis by a 10-man crew using 5 concrete or dumpcrete trucks and 2 gradalls to spread and work the grout into the rubble during 159 work weeks. The CSS grout-like material will be placed over the loose rubble using a spreader or chute on the rear of the truck with the truck driving to the side of the loose rubble. The CSS soil-cement material will be hauled, placed, and compacted like untreated soil over the rubble. Alternatively, the grout may be placed using a concrete pump and boom.

A 4-foot-thick clay top cover totaling 27,000 cubic yards will be placed over the waste in the cell. The material will be delivered from an off-site borrow source (within 5 miles) and placed at a rate of 80 cubic yards per hour by a 17-man crew using nine 10-cubic-yard end-dump highway haul trucks, a 988 loader, two D-6 dozers, a Raygo 400 compactor, a disk harrow, a grader to fine grade and maintain haul roads, and a water truck to maintain the specified moisture content and to control dust. This operation will require 43 work days to complete.

A 20,000-square-yard FML will be placed over the clay layer utilizing a crew of 8 and a tractor to unroll the material. Seams will be bonded by the placement crew and tested to assure that they meet quality control requirements. This operation will be completed over a period of 9 crew days at a rate of 20,000 square feet per day.

The next layer of the top slope will consist of 6 inches (3,000 yd^3) of filter material, followed by 1 foot (7,000 yd^3) of drain rock, topped by 6 inches (3,000 yd^3) of filter material. All of these materials will be purchased locally, delivered to the job site, and spread and compacted by a crew of 9 using a D-6 dozer, a 2-cubic-yard loader, a Raygo 400 smooth-drum compactor, and a water truck at a rate of 25 cubic yards per hour. Completion of this task will require 65 crew days. A 2-foot-thick frost protection layer totaling 14,000 cubic yards will be placed by a crew of 17 using a 988 loader, two D-6 dozers, a Raygo 400 compactor, a disk harrow, nine 10-cubic-yard end-dump trucks, a grader to fine grade, and a water wagon to maintain the moisture content of the material and control dust. At a rate of 80 cubic yards an hour, this operation will be completed over a period of 22 work days.

A 1-foot-thick riprap layer with choked rock surface will be placed at the top. Approximately 7,000 cubic yards of this material will be delivered to the site from a commercial source. It will be spread at a rate of 20 cubic yards per hour by a crew of 6 using a D-6 dozer, a 2-cubic-yard front-end loader, a grader, and a water truck over a period of 44 work days. Placement of sod or seeding will follow completion of the choked rock layer.

A 4-foot-thick clay cover layer totaling 241,000 cubic yards followed by a 3-foot-thick frost protection layer (181,000 yd^3) will be placed over the waste material on the side slopes. These zones will be constructed incrementally to coincide with the waste placement. The material will be delivered from the same off-site borrow source as for the top slope cover material. The rate, equipment and labor will be the same as required for the top slope. These zones will rise above the waste material and will be constructed concurrently with waste placement. Both cover components will be placed over a period of 660 crew days. When the side slopes have reached full height, 181,000 square yards of FML will be placed over the frost protection zone. Due to side slope conditions, by an 8-man crew, placement will be accomplished at a rate of 15,000 square feet per day over a period of 109 crew days.

The next layer of the side slope consists of 6 inches (30,000 yd^3) of filter rock, followed by 1 foot (60,000 yd^3) of riprap, topped by 6 inches (30,000 yd^3) of choke rock or soil. Materials for these cover components will be delivered to the job site for placement and compaction. The filter rock will be placed and compacted at a rate of 25 cubic yards an hour by a 6-man crew using a 2-cubic-yard loader, a D-6 dozer, a Raygo 400 smooth-drum compactor, and a water truck. This operation will require 150 crew days. Riprap will be placed at a rate of 30 cubic yards per hour by a 6-man crew using a D-6 dozer and a 235 backhoe. Riprap placement will require 250 crew days to complete. Choke rock will be placed by a 6-man crew at a rate of 20 cubic yards per hour using a 2-cubic-yard loader, a D-6 dozer, a grader, and a water truck over a 188-day work period. Placement of sod or seeding will follow completion of the choked rock layer.

Contaminated runoff within the cell will be contained by perimeter berms and ditches and directed to collection sumps or captured by the leachate collection system and pumped to lined retention ponds for storage prior to treatment.

The combination disposal facility will be constructed over a period of 6.5 years in three separate phases: Phase 1 beginning from Year 1 through Year 3, Phase 2 from Year 2 through 4.5, and Phase 3 from 4 through Year 6.5.

4.2.7 Facilities Closure

Removal of site facilities and emplacement within the on-site cell will follow completion of their use. Dismantling the TSA, the MSA, and the treatment plant will follow the final treatment of waste material. Dismantlement of the water treatment plant and the volume reduction facility will occur concurrently with road and embankment removal.

Final closure of the TSA will involve excavation of the sand and aggregate base, and related sediments after removal and emplacement of the stockpiled material. An estimated 22,000 cubic yards of material will be removed and hauled to the cell over a 5.5-work-week period at a rate of 100 cubic yards per hour. A 12-man crew will use a D-8 dozer, a 3-cubic-yard loader, a hoe ram, four 10-cubic-yard end-dump trucks, a grader, and a water truck to perform this task.

Reclamation of the 14,500 cubic yards of MSA foundation material will be performed over a 30-work-day period following recovery and cell emplacement of the stockpiled rubble and building materials. This activity will be performed at a rate of 74.2 cubic yards per hour (6.5-hour basis) with a 14-man crew using a CAT 235 backhoe, a hoe ram, a D-8 dozer, a 3-cubic-yard front-end loader, three 10-cubic-yard end-dump trucks, a rough terrain 15- to 24-ton hydraulic crane, a grader, and a water truck. Materials will be hauled to the disposal cell for encapsulation.

When chemical stabilization is complete, the concrete foundation and ramp materials at the treatment facility, approximately 900 cubic yards of material, will be removed and placed in the cell. An estimated 20 days are provided for this activity using a 4-man crew and a 2-cubic-yard loader, a hoe ram, a D-8 dozer, a rough terrain 15- to 24-ton hydraulic crane, two 10-cubic-yard end-dump trucks, and a flatbed truck. Foundation and other materials will be processed at the volume reduction facility.

Approximately 500 cubic yards of debris from dismantling the VRF will be removed over an estimated 20-day period using the crew and equipment employed for the removal of the chemical stabilization plant described above.

The final remediation activity will involve the removal of the site wastewater treatment facility. Fifteen days will be required to dismantle and remove approximately 400 cubic yards of debris material by a 14-man crew using a 2-cubic-yard loader, a hoe ram, a rough terrain 15- to 24-ton hydraulic crane, a flatbed truck, and two 10-cubic-yard end dump trucks. If required, a mobile water treatment unit will be brought to the site to support the final site closure activities following removal of the water treatment facility.

4.2.8 Site Regrading

Regrading activities will require importing various borrow materials and, as addressed here, will include the raffinate pits, chemical plant, and vicinity property areas.

4.2.8.1 Raffinate Pits. Restoration of the raffinate pit area will be accomplished by filling and grading the pits and surrounding areas to achieve uniform drainage. Reclamation is sequenced to complete pits 1 and 2 as soon as the soil and clay bottom is removed from those pits. Reclamation of pits 3 and 4 is delayed until the waste is removed from pit 4 to maintain dike integrity and to ensure the separation of contaminated water and waste from cleaned areas. Off-site borrow is assumed to be available within a 5-mile haul distance. The off-site material will be used for reclamation of pits 1 and 2 and for initial placement in pit 3. An estimated 111,400 cubic yards will be required at a rate of 117.3 embankment cubic yards per hour. The estimated 119 work days required to haul and place off-site borrow is based upon a 17-man crew using a 3-cubic-yard front-end loader, two D-6 dozers, a Raygo 400 compactor, ten 10-cubic-yard end-dump trucks, a water wagon, and a disk harrow. The remaining embankment in pits 3 and 4 will be placed at a rate of 619 cubic yards (adjusted to 8 hours per shift) of in-place embankment per hour, an estimated 37 work days will be required to place an estimated 180,000 cubic yards of berm. An 11-man crew will use four CAT 631 scrapers, two D-8 dozers, a Raygo 600 compactor, a grader, and a disk harrow.

Topsoil from an off-site source will be placed to a depth of 6 inches over the entire raffinate pit area when the basic site grading is completed. The 50,000 cubic yards of topsoil needed for this task will be hauled from an off-site borrow source. Over a period of 63 work days, a 10-man crew using a 3-cubic-yard front-end loader, two D-6 dozers, a Raygo 400 compactor, three 10-cubic-yard end-dump trucks, and a water truck will place the topsoil at a rate of 100 cubic yards per hour (adjusted to 8 hours per shift). The surface will be seeded with hardy native grasses.

4.2.8.2 Chemical Plant. After removal of the contaminated soils in the chemical plant area, approximately 263,000 cubic yards of backfill will be recovered from the chemical plant site and from outside borrow areas at a rate of 150 cubic yards per hour using a 3-cubic-yard front-end loader, a D-8 dozer, a grader, a Raygo 400 compactor, a disk harrow, six 10-cubic-yard end-dump trucks, and a water truck over a period of 220 work shifts. Approximately

37,000 cubic yards of topsoil will be imported and placed at a rated of 30 cubic yards per hour. The delivered material will be spread over a 155-work-shift period with a 3-cubic-yard front-end loader, a grader, a water truck, and a disk harrow. The entire area will be seeded with a variety of hardy, native, deep-rooted vegetation. Channel areas will be protected by riprap and choked with soil prior to seeding. The area within 200 feet of the cell toe will be graded away from the cell and transitions constructed to natural grade.

4.2.8.3 Vicinity Properties. Army properties 1 and 2 and Busch property 4 will be reclaimed with 1,648 cubic yards of backfill (including 575 yd^3 of topsoil) at a rate of 37.5 cubic yards per hour. The activity will be accomplished over a 6-work-day period with a 10.25-man crew using a 3-cubic-yard loader, three 10-cubic-yard end-dump trucks, a water truck, a Raygo 400 compactor, a D-6 dozer, a disk harrow (half time), and a grader (intermittently).

Army property 3 will be backfilled with 50 cubic yards of topsoil at a rate of 10 cubic yards per hour. This 1-work-day task will be performed by an 8-man crew using a 3-cubic-yard front-end loader, a Bobcat, a water truck, hand tampers, and one 10-cubic-yard end-dump trucks.

For reclamation of Army properties 1, 2, and 3 and Busch property 4, off-site borrow for backfill is assumed to be available within a 4-mile haul distance and that imported topsoil can be delivered to a location adjacent to the work site.

During reclamation of 14,000 square feet of disturbed area in Army properties 5 and 6, 850 cubic yards of rock material (one-half the volume of excavated waste) will be placed in the channel to prevent scour and downstream deposition of fines. The remaining half of the removed waste will be replaced by recontouring the banks to provide a stable channel. The 1,700 cubic yards of rock material and fill will be placed at a rate of 50 cubic yards per hour over a 5-work-day period. The 13-man crew will use a 3-cubic-yard front-end loader, a CAT 235 backhoe, a Raygo 400 compactor (smooth drum), a water truck, and five 10-cubic-yard end-dump trucks. Imported rock material will be delivered to an area near the work site.

4.3 Alternative 7A - Removal, Vitrification, and On-Site Disposal

Under this alternative, contaminated material will be processed at an on-site vitrification treatment facility and emplaced in an engineered disposal cell.

4.3.1 Site Preparation

The site preparation activities will be accomplished in the same manner as described for Alternative 6A in Section 4.2.1 above.

4.3.2 Excavation and Transportation of Waste Materials

Excavation and on-site transport of the Weldon Spring waste media will be accomplished in essentially the same manner under this alternative as described for Alternative 6A in Section 4.2.2, with the exceptions presented below.

Bench scale tests indicate that the vitrification treatment process requires feed materials which contain equal weights of sludge and soils. However, surface water will remain in the raffinate pits during sludge excavation in order to attenuate radon emanations and facilitate the sludge dredging operation described in Section 4.2.2. Therefore, the surface water will not be completely removed from the pits until after the sludge has been removed. As a result, the underlying soils will not be immediately available to meet vitrification feed material requirements. Determining the actual removal methods and schedule required to achieve the feed material requirements will require additional study and coordination.

The vitrification process will require continuous delivery of soil for processing or for blending with the raffinate pit sludge. For processing contaminated soil only, the required feed rate will be approximately 720 cubic yards per week. This feed rate requirement will be reduced to 360 cubic yards per week for vitrification of the raffinate pit sludge. An average delivery rate of 22.2 cubic yards per hour will be necessary, based on an operating schedule of a single 6.5-hour shift, 5 days per week. When only soils are being processed, material delivery will be performed over a 209-work-week period using a 3-cubic-yard loader to tram soils from the TSA to the plant feed bin.

Transport of fritted waste from the treatment facility to the disposal cell will require the loading and hauling of approximately 102,500 cubic yards of product over the 4-year period of plant operation. Assuming hauling is limited to 9 months each year, 36 haul months are available. With a 20-day operating period per month, average production on an 8-hour basis will be 17.8 cubic yards per hour and 21.9 cubic yards per hour on a 6.5-hour work basis. Loading and hauling will be performed either by a 5-man crew with a 3-cubic-yard loader or by direct discharge from the hopper into two 10-cubic-yard end-dump trucks, supported by a water truck (half time), a grader (quarter time), and a D-6 dozer (quarter time). This crew will also load and haul 15,400 cubic yards of clay binder to the disposal cell over the course of placement operations.

The vitrification plant will operate on a 24 hours-per-day, 12-months-per-year schedule. The fritted material produced during the winter months (6,400 yd^3) will either be stored adjacent to the treatment facility or in the TSA. The front-end loader will be used to transfer the treated material to storage.

4.3.3 Volume Reduction

Volume reduction of selected materials will be accomplished as described for Alternative 6A in Section 4.2.3.

4.3.4 Metals Decontamination

Selected metals may be decontaminated using the methods described in Section 4.2.4 for Alternative 6A.

4.3.5 Vitrification

Vitrification using a fossil fuel-heated ceramic melter (FFHCM) has been identified as a viable method of treatment for selected waste media at the Weldon Spring site. The following discussion is based on a number of assumptions regarding the waste material to be vitrified.

The raffinate sludge will be dewatered to a target moisture content of 20% when it is fed to the physical preparation circuit. The sludge dewatering facility has not yet been designed. However, the results of an MKES study (1992a) suggest that it may be possible to generate a dewatered product with an 80% solids content using a cyclone and a plate and frame filter system. Alternatively, dewatering could also be performed using a belt press, screens, and flotation. Additional studies are required to identify an optional dewatering system.

The dewatering facility will operate 9 months per year, and the estimated 3,500 tons of dewatered material that is produced by this facility and not vitrified by the end of that 9-month period will be stockpiled in an enclosed storage area at the treatment facility. A 45-day period will be required to vitrify the remaining stockpiled dewatered sludge. Contaminated water resulting from waste dewatering will be treated at the site water treatment plant or returned to the raffinate pits. Dewatering is necessary to minimize the impact of excess steam generation on the effectiveness of the off-gas treatment system, and to reduce the volume of material to be treated.

Raffinate sludge dewatered to 80% solids will have a bulk density of 1.32 tons per cubic yard. The dewatered material will be dried during physical preparation prior to vitrification, resulting in a bulk density of 1.06 tons per cubic yard. The soils and clay bottom will also be dried during physical preparation to an assumed bulk density of 1.37 tons per cubic yard.

A number of process operational assumptions have also been incorporated into this treatment alternative. Vitrification will begin concurrently with raffinate dredging and dewatering. The throughput for the treatment of all waste materials during the 4-year operating period will be 125 tons of solids per day. The energy consumption required for vitrifying all wastes is assumed to be 4.5×10^6 Btu/ton. This requirement is consistent with data reported by Battelle Pacific Northwest Laboratory (PNL) (Koegler et al. 1989); data provided by commercial glassmakers (MKES 1992e); and by Vortec Corporation personnel. Estimates of volume/tonnage of vitrified glass produced assume no loss of solids during vitrification (loss on ignition), and that the tonnage of glass produced is equal to the tonnage of waste solids fed to the treatment facility. Refractories for the melter can be designed and/or acquired which will have a design life in excess of the vitrification project life. It is also assumed that all wastes from the primary off-gas scrubber can be recycled through the melter. The melter is assumed to be operable 90% of the time.

The waste glass product is assumed to have a solid density identical to that of quartz. In fritted form, the vitrified glass will have a bulk density of 1.78 tons per cubic yard, which includes 20% (vol.) void space.

4.3.5.1 Site Preparation. The vitrification treatment facility, including the material physical preparation circuits, will be located along the southeast corner of Raffinate Pit 3. An area approximately 450 feet by 100 feet has been designated as the site of the treatment facility. This area is adequate for the proposed vitrification plant and will be presumed to have been graded and prepared for plant construction using equipment used for waste excavation and other site construction activities. Preparation of this relatively small area is described in Section 4.2.1. Excavation, placement of foundations, and installation of underground utilities will be completed as equipment is assembled on site for mechanical installation.

4.3.5.2 Materials to be Vitrified. Waste materials identified for vitrification will include the raffinate sludges from pits 1, 2, 3, and 4, the clay bottom material from those pits, and contaminated soils from the quarry. The estimated quantities, densities, and moisture contents of the wastes to be vitrified are presented in Table 4-11. Quantity estimates are based on the same assumptions defined for CSS in Section 4.2.5.

TABLE 4-11 Waste Material to be Vitrified

Material	Volume yd3	Density t/yd3	Tonnage	Moisture %	Dry Tons
Pit 1 Sludge	17,400	1.01	17,600	73 %	4,752
Pit 2 Sludge	17,400	1.01	17,600	73	4,752
Pit 3 Sludge	129,400	1.01	130,700	73	35,289
Pit 4 Sludge	55,600	1.01	56,100	73	15,147
Pit 1 Clay bottom	2,440	1.52	3,709	20	2,967
Pit 2 Clay bottom	2,440	1.52	3,709	20	2,967
Pit 3 Clay bottom	15,785	1.52	23,993	20	19,195
Pit 4 Clay bottom	29,335	1.52	44,589	20	35,671
Quarry Soils	50,000	1.52	76,000	20	60,800
WTP residuals	3,600	0.94	3,400	73	918
Drummed waste	28	0.82	23	73	6
Totals	323,428		377,423		182,464

The raffinate sludges and clay pit bottoms are contaminated with varying amounts of radionuclides, heavy metals, metalloids, and anionic species (DOE 1992b). The contaminants of concern in the quarry soils are reported to also include nitroaromatic organic compounds such as dinitrotoluene and trinitrotoluene (DOE 1989). Fossil fuel-heated ceramic melting is the vitrification method least susceptible to problems caused by variation in feed materials chemistry. This process is also projected to be the least costly vitrification method (MKF and JEG 1992a).

Information summarized in other reports (Koegler et al. 1989, MKES 1992c) indicates no fatal flaws in the vitrification of the above materials using fossil fuel-heated ceramic melting.

4.3.5.3 Feed Preparation Requirements. Vitrification of waste materials requires that certain glass-forming compounds be present in the waste. Because melted raffinate excessively devitrifies, silica-rich soil is needed to add adequate glass-forming compounds to the raffinate sludge for melting. Koegler et al. (1989) have shown that a blend of 1:1 dry raffinate solids to dry soil solids melted at 1,250°C, had a viscosity of 800 to 1,000 poise and generated a satisfactory glass product. This same mixture had a viscosity of 200 poise at 1,475°C. Soil alone melted at 1,440°C and had a viscosity of ≥3,000 poise. Fossil fuel-heated ceramic melters are capable of handling fairly viscous melts. Vortec representatives (1991a) stated that their FFHCM units are capable of processing melts with viscosities in the thousands of poise. It is therefore assumed that for vitrification the raffinate sludge will be mixed with soil or clay pit bottom material in a 1:1 ratio of dried solids and that the soils or clay bottom remaining can be vitrified alone. The addition of melt modifiers such as soda ash, silica, or borate is assumed to be unnecessary.

Fossil fuel-heated ceramic melters require waste (feed) sizing and blending prior to treatment but can accept waste with any moisture content. To assess the effects of feed material moisture content, preliminary studies have evaluated dewatering of the raffinate sludge prior to vitrification treatment (MKES 1992a and e; MKF and JEG 1992a, Koegler et al. 1989). The results of these studies indicate that physical dewatering prior to vitrification would be less expensive than thermally removing the water during vitrification. The generation of excess steam during vitrification of non-dewatered raffinate would also cause increased costs for the design, construction, and operation of the off-gas treatment system. For these reasons, it is assumed that the raffinate sludge delivered to the treatment facility will have been previously dewatered to a target of 80% solids.

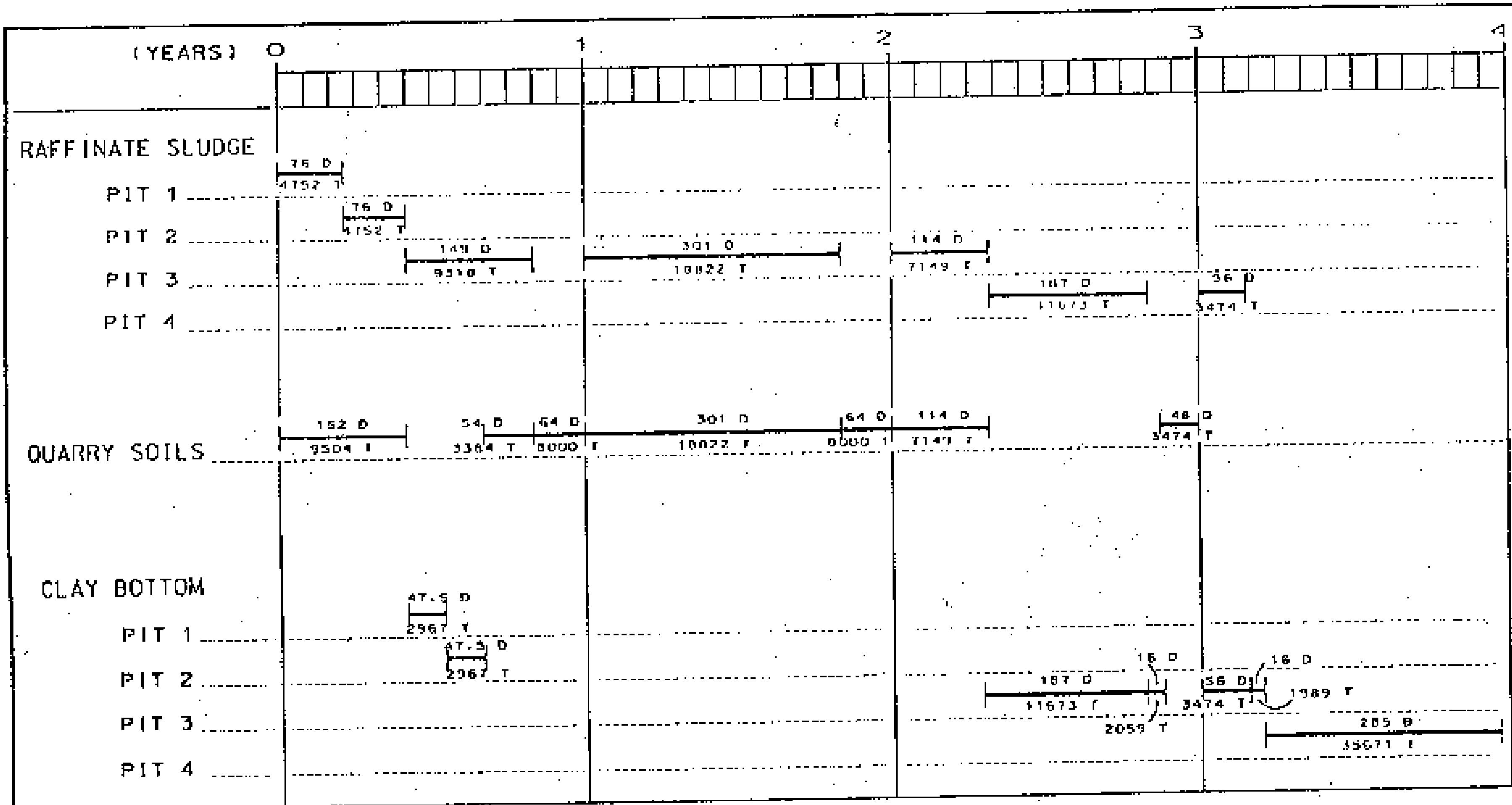
All materials should be sized to minus 1 millimeter prior to vitrification (Vortec 1991a). The material preparation circuits will operate 12 months per year, 1 shift per day, 5 days per week, with 6.5 hours of productive time per day assumed. A 7-day supply of waste materials prepared for vitrification will be stored in enclosures designed to prevent fugitive dust emissions. These waste materials will be delivered to the melter via an enclosed manifolded belt delivery system. The melter operator will be able to chose the particular materials and the appropriate blending ratios to be delivered to the melter using an automated control system.

4.3.5.4 Treatment/Production Rate. The vitrification treatment rate will be 125 tons of solids per day, 365 days per year. This rate will accommodate treatment of all of the selected materials during a period of approximately 4 years. The materials handling, physical pretreatment, materials storage, and vitrification equipment are sized to accommodate a total of 200 tons of waste per day received at 80% solids. These equipment sizes include allowance for the projected 90% availability and a 15% oversize of required throughput.

4.3.5.5 Scheduling of Materials to be Treated. Waste materials will be delivered to the treatment facility during the 9 construction/excavation months of the year. Since the treatment facility will operate 12 months per year, some stockpiling of materials will be necessary. As previously mentioned, raffinate sludges, raffinate pit clay bottom, and quarry soils are the materials to be treated. Raffinate sludge will be mixed with quarry soil or clay bottom prior to treatment, as recommended by PNL (Koegler et al. 1989). The raffinate sludge and clay bottom will only be excavated during 9 months of the year. The designed throughput of materials for the melter is slightly less than the excavation rate for the raffinate sludges; therefore, a 45-day supply of dewatered raffinate sludge will need to be stockpiled at the treatment facility. The quarry soil, stockpiled prior to the initiation of operations, and raffinate clay bottom material stored at the TSA will be available as feed during the 3 months per year that the construction/excavation activities are shut down.

Figure 4-6 and Table 4-12 present a preliminary waste treatment schedule to illustrate the interface between sludge and soil processing. The raffinate sludge from pits 1 and 2 will be treated with quarry soils. When the raffinate sludge from pits 1 and 2 is exhausted, treatment of the raffinate sludge from pit 3 will begin. It is assumed that clay bottom from pits 1 and 2 will be available for treatment at this time. If there is a delay in determining the depth of contamination in the pit clay bottom, for example, quarry soils can be substituted until the clay bottom material is made available for treatment. Similarly, at the completion of treatment of raffinate sludge from pit 3, treatment of raffinate sludge from pit 4, and clay bottom from pit 3 will be initiated. Again, if for some reason the clay bottom from pit 3 is not available at that time, quarry soils can be substituted. The goal of scheduling the waste for treatment is to treat materials as they are excavated, thereby minimizing the quantities of materials stockpiled. Stockpiled materials will be treated during the 3 months that construction/excavation activities are shut down. The materials produced during the 3-month winter shutdown (6,400 yd^3) will be stored at the TSA or in an adjacent stockpile.

4.3.5.6 Process Description. The following narrative describes the vitrification process for treating selected Weldon Spring site waste materials using fossil fuel-heated (natural gas)



LEGEND

D = DAYS

T = TONS OF WASTE (100% SOLIDS)

WELDON SPRING

SCHEDULE FOR VITRIFICATION OF W S S R A P WASTES

Figure 4-6

REPORT NO.:	DRAWING NO.: WD3840/WS1SCH.DGN	
ORIGINATOR: JA	DRAWN BY: DJ	DATE: 4-91

TABLE 4-12 Annual Quantities of Materials Vitrified (Tons of Solids)

Material	Year 1	Year 2	Year 3	Year 4	Total
Raffinate Sludge					
Pit 1	4,752				4,752
Pit 2	4,752				4,752
Pit 3	9,318	18,822	7,149		35,289
Pit 4			11,673	3,474	15,147
Quarry Soils	20,888	26,822	13,090		60,800
Clay bottom					
Pit 1	2,967				2,967
Pit 2	2,967				2,967
Pit 3			13,732	5,463	19,195
Pit 4	—	—	—	35,671	35,671
Totals	45,644	45,644	45,644	44,608	181,540

Note: Excludes water treatment plant residues and drummed solid wastes.

ceramic melter technology. Included in the discussion are all aspects of the treatment process, from the delivery of materials to the treatment plant through the production of the final vitrified waste form. Construction of the full-scale plant is anticipated to be completed within 4 years of the initiation of bench-scale testing. After operating the full-scale system for 3 to 6 months, the operating parameters for the system should be adequately optimized.

4.3.5.6.1 Physical Pretreatment Circuits. Two separate physical pretreatment circuits will be used: a circuit to treat the dewatered raffinate sludge and a circuit to treat both the quarry soils and the raffinate clay bottom. These separate circuits will be required due to the differences in the feed materials; the two circuits also increase the flexibility and reliability of the complete system. The exhaust air from the buildings which house the physical treatment equipment will be routed to a baghouse where it will be filtered. The particulates from this filtration will be collected and mingled with the melter feed material via a screw conveyor; the clean filtered air will be exhausted to the atmosphere. Water from the dewatering plant and water removed during physical pretreatment will be pumped to the site water treatment plant or returned to the raffinate pit.

- **Raffinate Sludges Pretreatment Circuit.** The dewatered raffinate sludge stored at the dewatering facility will be fed into a hopper which will feed an underground chain conveyor to transport the material to the building which houses the physical treatment circuit. This conveyor will discharge the raffinate sludge after tramp iron removal to a double-roll crusher which has enhanced efficiency over a single roll crusher, and will act as a crusher/delumper and will size the sludge to minus 3/8 inch. The minus-3/8-inch material will then be screw conveyed to a roller mill where it will be further sized to minus 1 mm. This mill will be equipped with a natural gas drier to eliminate fouling of the mill by wet materials. The air from the drier will be filtered and then condensed. The condensate will be sent to the water treatment facility, and clean air released to the atmosphere. The sized material will be pneumatically transferred to a 650-ton storage bin equipped with a filtered vent to eliminate fugitive dust emission. The treated sludge in storage represents a 10-day stockpile for the melter. This stockpile will provide feed to the melter circuit during equipment maintenance and holidays. A remote-controlled variable speed screw conveyor will transport the prepared sludge to a pug mill where it will be blended with soil or clay at the desired ratio. This mixture will be split and screw conveyed to the precombustors in the two melter circuits.

- **Soil and Clay Pretreatment Circuit.** Although treated by one feed preparation circuit, the quarry soil and raffinate pit clay bottom material will not be processed together and are discussed separately. The quarry soil will dumped and fed through a vibrating grizzly within an enclosed building to remove material larger than 1 inch. This material will be collected in a bin and returned to the TSA for disposal with other materials or transported directly to the disposal facility. The grizzly will be removed during treatment of the clay bottom. The quarry soil or clay bottom, hereinafter referred to as soil, will then be belt conveyed past a tramp iron magnet and discharged to a double-roll crusher which will act as a crusher/delumper and will size the soil to minus 3/8 inch. The minus-3/8-inch material will then be screw conveyed to a roller mill where it will be further sized to minus 1 millimeter. This mill will be equipped with a natural gas drier to eliminate fouling of the mill by wet materials. The air from the drier will be filtered and then condensed. The condensate will be sent to the water treatment facility, and the clean air released to the atmosphere. The sized material will be pneumatically transferred to 650-ton storage bins equipped with filtered vents to eliminate fugitive dust emission. One bin will store clay bottom and another will store quarry soil. The combined treated soil in storage represents a 10-day stockpile for the melter. This stockpile will provide feed to the melter circuit during equipment maintenance and holidays. A remote-controlled variable speed screw conveyor will transport the prepared soil to a pug mill where it will be blended with the raffinate sludge at the desired ratio. This mixture will be split and screw conveyed to the precombustors in the melter circuits.

4.3.5.6.2 Vitrification Treatment Circuit. This vitrification alternative was developed based on the use of a fossil fuel-heated ceramic melting system designed by Vortec Corporation. This melting system must be able to accommodate a total of 200 tons of waste at 80% solids per day, 365 days per year. To achieve this feed rate, two 100-ton-per-day (tpd) melter units have been selected. The reasons for using two units instead of one 200-tpd unit are that scaling up to the smaller size unit presents less difficulties in design and that the duplication of units will likely prevent shutdown of total melting capacity of the treatment facility, thereby increasing its flexibility and reliability. Additional bench- and pilot-scale testing will be required to determine process variables, such as energy consumption, range of acceptable raffinate pit sludge to soil ratio, minimum required operating temperatures, partitioning of contaminants between melt and off-gas, and the amount and type of physical pretreatment required.

The combustion/melting systems each consist of three primary assemblies: (1) a precombustor chamber, (2) an in-flight counter rotating vortex (CRV) heater, and (3) a separation/melting chamber.

- **Precombustor Chamber.** The prepared waste material will be fed to the precombustors where initial preheating and drying of the waste occurs. The heat energy supplied to the precombustors comes from the recuperators where heat energy in the melter off-gases is transferred to fresh air for combustion. This fresh, heated air is fed with the waste materials to the precombustor. The combustor gasses and dried waste materials are then discharged into the CRV.

- **Counter Rotating Vortex Heater.** Fuel will added to the CRV with the combustor gases and dried wastes. While in suspension, the waste materials are rapidly and efficiently heated to glass-forming temperatures in the CRV: 1,250°C for the sludge and soil/clay mixture and 1,440°C for soil or clay alone. The intense counter rotating vortex mixing enables stable combustion in the presence of large quantities of inert particulates. Organic contaminants, such as the nitroaromatics in the quarry soils, are effectively oxidized in the process. The combustion gasses and preheated materials are discharged from the CRV into a cyclone reactor where melting reactions occur. Figure 4-7 is a drawing supplied by Vortec of its 100-ton-per-day CRV heater and cyclone reactor systems, model number VC-48A. Each of these units weighs 55,750 pounds.

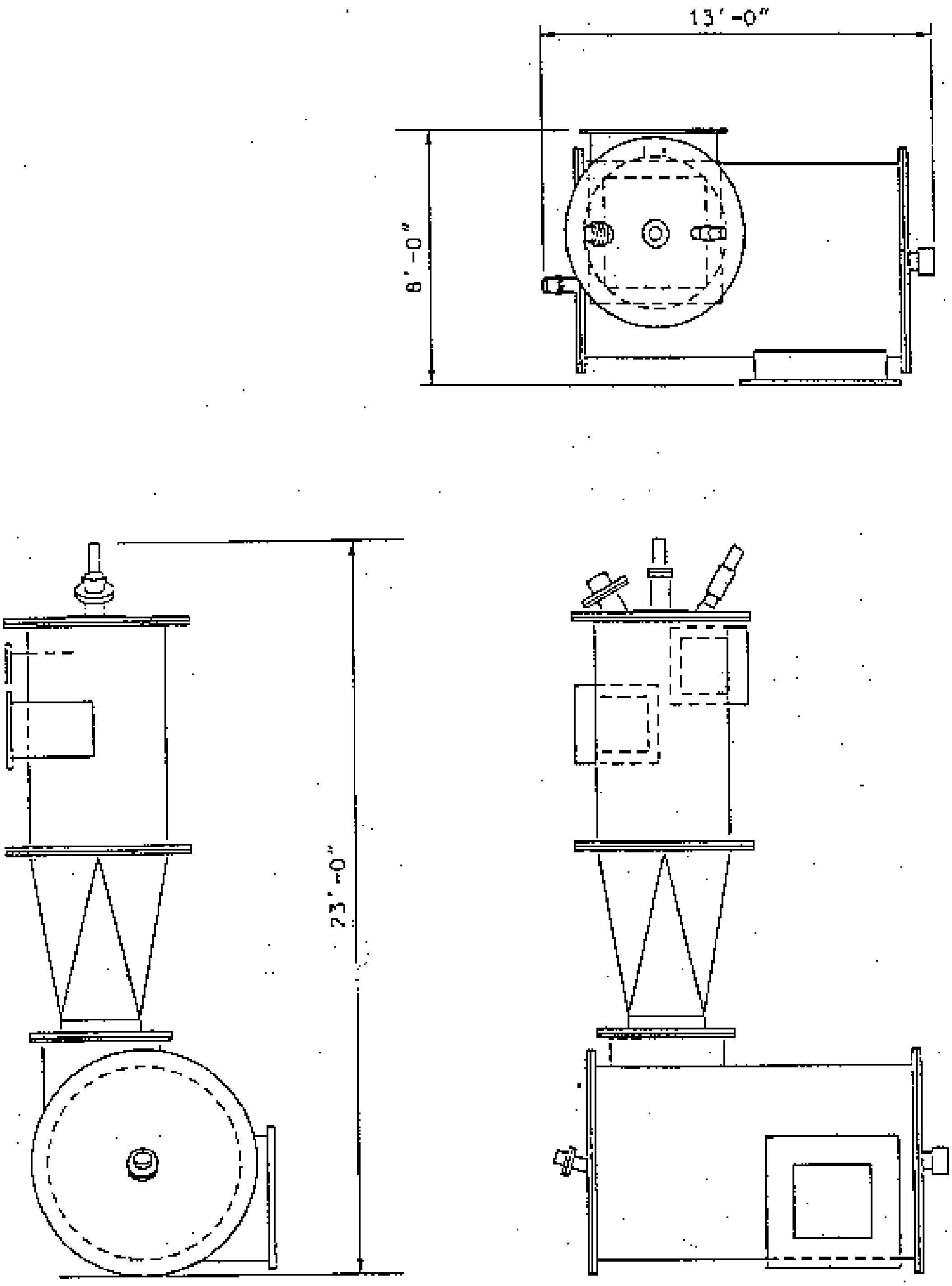
- **Cyclone Separation/Melting Chamber.** The melted product formed in the cyclone reactor, as well as the combustion products, will exit the cyclone reactor through a tangential channel and enter a separator/reservoir where a pool of the melted material will be collected. The primary function of the glass separation/reservoir assembly is to separate the combustion products from the melted material and to provide sufficient residence time, approximately one hour, for completion of the glass-forming reactions. In addition, the reservoir can be used to recycle solid waste from the off-gas cleanup system back into the molten glass bath. The hot exhaust products exit the melt reservoir through an exhaust port located on the side or top of the assembly and continue to the off-gas treatment system. The molten product is immediately quenched in water which produces a fritted glass product ranging in diameter from ⅛ to ¼ inch.

- **Vitrified Product Handling System.** The frit will be collected in hoppers, and submerged drag conveyors will be used to dewater the frit and transfer it to 400-ton bins to await haulage to the on-site disposal facility. The fritted vitrified product will be produced at a rate of approximately 125 tons per day, 7 days per week, resulting in 875 tons of vitrified product per week. At 1.78 tons per cubic yard, this rate corresponds to 70 cubic yards per day or 492 cubic yards per week. Two 400-ton bins allow for the storage of approximately one week's production. The 6,400 cubic yards of fritted glass produced during the 3 winter months while cell operations are shutdown will be stored in a 6,400-cubic-yard (maximum) storage pile adjacent to the treatment plant or at the TSA.

4.3.5.6.3 Equipment. The following equipment will be required for the vitrification treatment process previously described.

Raffinate Sludge Pretreatment	$682,500
Soil and Clay Bottom Pretreatment	1,144,000
Feed Blending Equipment	179,000
Vitrification Product/Product Handling	2,718,000
Buildings	1,574,000
Off-gas Treatment System	716,200

The installed cost of this equipment is estimated to be approximately	$25,300,000



MODEL NO. VC-46A

NOM. CAPACITY TONS/DAY = 100

ESTIMATED WEIGHT = 55.750 LBS.

WELDON SPRING

OUTLINE DRAWING OF BASIC VORTEC COMBUSTION MELTING SYSTEM

Figure 4-7

REPORT NO.:		DRAWING NO.: W03840/VSTSCH.DGN
ORIGINATOR: JA	DRAWN BY: DJ	DATE: 4-91

Gas Pipeline	300,000
	$25,600,000
Dewatering Equipment	1,700,000
TOTAL INSTALLED COST	$27,300,000
Bench and Pilot Testing	8,200,000
TOTAL PLANT COST	$35,500,000

Approximately 48 months will be required for additional bench-scale testing, pilot-scale testing, and final design. All costs are based on vendor quotes and engineering estimates.

4.3.5.6.4 Product Verification Testing. The final vitrified product will be tested to assure that the product meets design specifications for leach resistance. Product leaching tests which will be conducted include Material Characterization Center tests MCC-1 and MCC-3, and the Toxicity Characteristic Leaching Procedure (TCLP). Although leaching of vitrified products varies to a small degree with product form, it is expected that vitrified Weldon Spring site waste material will pass any of the previously mentioned leaching tests.

Samples of the vitrified product will be continuously and automatically collected during process operations. Each shift, these samples will be archived on-site as composites. Any changes in feed materials or other operating parameters, which the operator or process engineer determines may affect product quality, will also be cause to archive composites. If any material does not pass during routine process sampling, process modifications will be implemented for subsequent treatment batches. The product represented by the failed sample would not be removed from the cell.

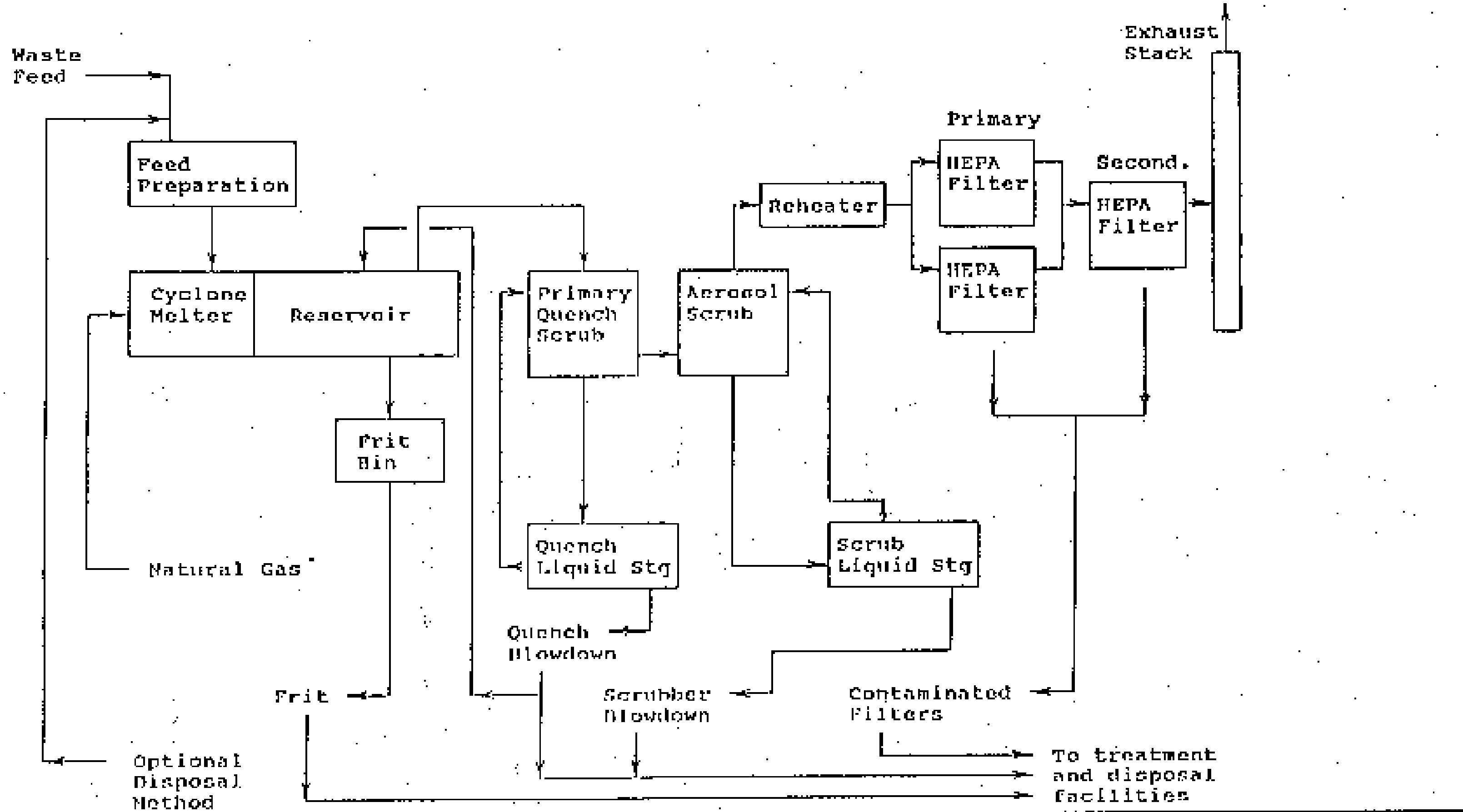
The treatment process operating parameters will be optimized during pilot testing. The fritted glass produced during start-up testing will need to consistently pass the disposal criteria before full-scale operations can begin. The frequency of testing required to assure product quality will be established during start-up operations. After the initial 3- to 6-month start-up period, it is anticipated that weekly testing will be adequate.

4.3.5.6.5 Off-Gas Treatment System. Off-gas treatment systems for vitrification processes must be designed to quench the high-temperature off-gas and remove entrained dust, submicron aerosol, and any unacceptable levels of non-condensible gases created during vitrification of the waste or combustion of the fuel. In addition, if the feed material contains radionuclides, a final high-efficiency filtration step is required. Thus, for the Weldon Spring waste profile, the off-gas treatment system must include, at a minimum, a primary quench scrubber, an acid-gas/submicron aerosol scrubber, and a high-efficiency final filtration device. Heat removal will be accomplished by a combustion air pre-heating recuperator and/or a scrubber water cooling system. Radon control will not be required and NOx control does not appear to be necessary. However, annual air quality modeling will be required for confirmation. The off-gas treatment unit operations are shown schematically in Figure 4-8 and are described in more detail below. Conservative control efficiencies are reported for the primary contaminant classes based on EPA estimates (Federal Register 1989) and vitrification literature.

Off-gas Cooling. Waste heat in the off-gas can be recovered and used to preheat the combustion air in a radiation recuperator or to heat air for use in the physical preparation circuits, reducing the size of gas heaters and their fuel costs. A counter-current, low-fouling recuperator may recover up to 25% of the input heat load while pre-heating the combustion air by up to 1100°F (590°C). Deposition of solids in the recuperator as the off-gas cools and vapors condense is a potential problem with this heat recovery option--a problem that should be carefully evaluated during a pilot-scale test of the system. In the event of unacceptable solids buildup, a low-fouling, wet quench scrubber, such as a deluge tower with liquid-liquid heat exchangers, may be required for heat removal at the expense of heat recovery. Film coolers have been used in some joule-heated vitrification processes to cool without fouling (Scott et al. 1985). Film coolers, however, would not be suitable for the large off-gas volumes resulting from fossil-fuel combustion.

Quench Scrubber. A primary quench scrubber is required to quench the hot off-gas, to remove gross entrainment dust particles, and to begin acid gas scrubbing. Quench scrubbers that have been used in incineration and vitrification processes include ejector-venturi scrubbers (EVS), submerged bed scrubbers (SBS), spray towers, jet bubbling scrubbers, and plate column scrubbers. Spray towers provide very low scrubbing efficiencies, and the bubbling-type scrubbers are limited to the much lower off-gas volumetric flow rates attained by joule-heated systems.

The preliminary design concept is based on an ejector-venturi scrubber system for the primary quench scrubber. It can be scaled up easily to a 100 tpd fossil-fueled melter flue gas flow volume and provides relatively high scrubbing efficiencies for the quench scrubber class. EVSs are simple, stable, and easy to control for optimum performance. Based on EPA's "conservatively estimated" control efficiencies (Federal Register 1989), the EVS is assumed to attain 90% control of non-volatile metals and gross entrainment aerosol, 20% control of mercury and other volatile metals (As, Cd, Pb, Se), and 50% control of acid gases (CARB 1989).



GENERIC VITRIFICATION UNIT BLOCK FLOW DIAGRAM

FIGURE 4-8

REPORT NO:			EXHIBIT NO:	A/PI/196/1292	
ORIGINATOR	JAB	DRAWN BY: GLN		DATE:	12/92

Nitrogen oxides control, although highly uncertain, is conservatively expected to be 7% (estimated from Brunner 1984). The EVS is not assumed to provide significant control for residual organics or radon.

Submicron Aerosol Scrubber. A high-efficiency scrubber is required to remove the volatilization/condensation aerosol loading that occurs primarily in the submicron size range and to scrub more efficiently any remaining acid gases. High-efficiency scrubbers may include high-energy venturi scrubbers, steam-atomizing or tandem-nozzle scrubbers, or high-efficiency mist eliminators (HEME). The HEME scrubbers consist of deep fiber beds that are very susceptible to plugging and are only recommended for soluble contaminants that can be backwashed with a water flush (Sehmel 1990).

The proposed preliminary conceptual design submicron aerosol scrubber is a Hydro-Sonic Scrubber. The Hydro-Sonic Scrubber is a simple, highly efficient gas- or steam-atomizing scrubber that may be used singly or in series for extremely high overall efficiencies. Hydro-sonic scrubbers have been repeatedly demonstrated to provide up to 99.9% control of particulates and acid gases. Control efficiencies assumed for a high-energy scrubber, however, are based upon EPA's conservatively estimated values of 98% for gross particulates and non-volatile metals; 40% for volatile and semi-volatile metals, including mercury (Federal Register 1989); 90% for acid gases (CARB 1989); and 25% for NOx (estimated from Brunner 1984). No control is assumed for organics or radon.

Nitrogen Oxides Control. Most vitrification off-gas treatment systems researched did not have NOx control equipment. However, because of the potentially high concentrations of nitroaromatics and nitrate in the Weldon Spring waste, NOx emissions could require controls. Since there are no direct emission-limiting ARARs for NOx, air dispersion modeling and comparison to the annual NO_2 National Ambient Air Quality Standard is required to determine whether NOx control is necessary. If dispersion modeling reveals violations in ambient NOx standards, there are several possible NOx abatement methods that might be usable for this type of melter.

Catalytic reduction of NOx with ammonia may be the most attractive NOx control methodology, if process design cannot reduce NOx emissions to acceptable levels (Armstrong and Klinger 1985.) This process involves injecting ammonia into the gas stream to react with NOx to form nitrogen and water. The major advantage of this system is that no by-product waste, such as increased scrubber sludge, is produced. NOx removal efficiencies have been estimated at 99% for this method (Donato et al. 1984).

A major disadvantage of the system is that operational parameters must be carefully controlled. The NH_3/NOx ratio and the temperature of the off-gas must be carefully controlled to avoid formation of ammonium nitrate, an explosive. This may dictate the use of upstream NOx and temperature monitors which control the ammonia injection.

Other NOx control options include nonselective catalytic reduction technologies, flame reduction (NOx is reacted with excess fuel at high temperatures in a combustion chamber), or enhanced gas scrubbing methods such as packed absorber columns.

Final Filtration. The final filtration process is required to attain the lowest achievable emissions of radionuclides. Vitrification melter emissions are typically reported as "off-gas decontamination factors" (DF). Off-gas DFs represent the rate a species is fed to the melter divided by the rate that it is released to the off-gas stream. For example, a very volatile material that is 100% volatilized into the off-gas stream would have a DF of 1. If 50% of a compound is released into the off-gas the DF is 100/50 or 2; if 1% is released the off-gas DF is 100/1 or 100, etc.

A typical final filtration system will include a gas preheater, roughing filters, a primary high efficiency particulate air (HEPA) filter set in parallel for maintenance flexibility, and a secondary HEPA system in series with the primary HEPAs for system backup. HEPA efficiency is conservatively assumed to be 99.95% (DF=2000) for removal of submicron aerosol particles per HEPA stage. Only the primary HEPA control efficiency is applied to the estimated particulate emission for this conservative analysis. The reheater typically heats the flue gas from a scrubber outlet temperature of 170 - 190°F (77-88°C) by 25°C, to approximately 215 -235°F (102 - 113°C). HEPA filters are not expected to provide any control for mercury, radon, acid-gases, or organics.

Stack/Blower System. Following the final pollution control devices, dedicated 15,000-cfm blowers, a dampered manifold system, and common stack are proposed. Separate, dedicated off-gas systems are recommended for each 200 tons per day treatment unit to maintain operating stability and flexibility, but a common stack may be used for releasing the off-gasses. A stack height of 100 feet (30 m) is recommended, based on a vitrification building height of 40 feet and the Good Engineering Practice stack height rule (2.5 times building height) for prevention of building wake downwash.

Radon. Radon emissions will result from two separate mechanisms. First, all radon present in the soil going into the melter will be released to the off-gas stream. Second, some radon will be generated while the material is in the melter. The amount of radon present in the material to be vitrified was calculated based on the following assumptions:

- Radon will be in secular equilibrium with Ra-226 in the material to be vitrified. This means that radon will be generated at the same rate as it is decaying, and the only radon loss is through decay. Based on this assumption, no radon escapes from the soil. Therefore, the radon activity level in the material will be equal to the radium activity level. In actuality, the radon activity level will be less because of the radon flux from the soil.

- No radon will escape from the soil or sludge while the material is excavated and transported to the melter. Again, this is a very conservative assumption.

Although these assumptions may be unrealistically conservative, other calculation methods would require extensive study on the gas retention properties of the material to be vitrified and the effect of excavation activities on the radon release.

To calculate the amount of radon generated while the material is being vitrified, material was assumed to have a 1-hour retention time in the melter. It was also assumed that all radon generated while the material is in the melter will be emitted to the off-gas stream. Preliminary calculations for anticipated radon emissions are summarized below. If compared to the radon emission requirement of 5×10^{-5} μCi/ml in the off-gas (DOE Order 5484.1) discussed by Koegler et al. (1989), it may be concluded that radon control may not be necessary. An absence of radon control for all operating high-level vitrification processes supports this possibility.

Parameter	max 1-hour	max 24-hour	average annual
Emission in Ci	0.024	0.58	24
Emission in μCi/ml of off-gas[(a)]	1.12×10^{-6}	1.12×10^{-6}	2.0×10^{-7}

(a)

A minimum flow rate of 92,000 ft³/ton of feed was used to calculate emission rates.

Fate of Contaminants. Fick's First Law of Diffusion is used to predict leach rates based upon contaminant concentrations within the glass product, the diffusion coefficient, and the surface area. Product form affects only the surface-to-volume ratio. However, because of the extremely low diffusion coefficients in a silica-rich glass material (10^{-12} to 10^{-13} cm/sec), contaminant flow from all product forms is low. The leach rates of the vitrified product are similar to those of volcanic glass (obsidian), which has been age-dated in millions of years and demonstrates millimeter-thick weathering rinds having the same chemical composition as the rock interior.

Based on the leach rates of various vitrified products, it is anticipated that the fritted product will easily pass all criteria for land disposal. During evaluation of in situ vitrification as a possible process option, PNL conducted bench-scale tests using raffinate pit sludge and soil from the Weldon Spring site. These tests produced a product which passed the EP-TOX test (Koegler et al. 1989). It is anticipated that the vitrified product will also meet TCLP testing requirements.

At the high operating temperatures and residence time of the contemplated fossil fuel-heated ceramic melting process (1200°C to 1450°C), the nitroaromatics and other organic constituents would be completely destroyed. Nitrates would also be destroyed by the vitrification process. The nitrates (NO_3) would be converted to gaseous molecules (NO_2, H_2, and NO_x). The nitrogen converted to NO_x could be abated by control components in the off-gas treatment system if required. However, the majority of the nitrates are quite soluble and would be removed during the sludge dewatering process. The nitrates and other soluble compounds would be contained in the wastewater from the dewatering circuit that would be treated in the water treatment plant to acceptable levels of contaminants.

Similar to the nitrates, some of the sulfates would be volatilized during the melting process and captured in the off-gas treatment circuit. Section 5.2.3 presents this discussion on more detail. Table 5-3 shows the estimated amount of contaminants in the waste feed to the vitrification facility and their estimated fate after vitrification.

4.3.5.6.6 Manpower. The total manpower required to operate and maintain the physical pretreatment and melting circuits is summarized below:

Circuit	Type of Personnel	Number Required
Pretreatment	Supervisor	1
"	Operators	2
"	Maintenance	2.5

"	Laborers	2
Melter	Process Engineer	1
"	Operators	4
"	Maintenance	4.5
"	Laborers	4

The process engineer will supervise the operations of both the physical pretreatment and melting circuits. This individual will be a degreed engineer with a chemical, metallurgical, or ceramic background. He will work during the first shift and will supervise the scheduling of materials to be treated, changes required to optimize pretreatment and melting circuits, maintenance schedules of all equipment, and the monitoring of process operations and off-gas systems to assure that both the process and the product comply with required specifications.

The pretreatment circuit will operate 5 days per week, 1 shift per day. A supervisor will be required to oversee both treatment circuits. This individual will have previous materials sizing/grinding experience; a college degree in a related discipline is desirable but not necessary. An operator will be assigned to each individual pretreatment circuit: raffinate sludge or quarry soil and clay bottom. These operators will monitor the operation of their respective circuits to assure that equipment is operating at required rates and up to specification. Two maintenance personnel will work together to maintain all three circuits (two pretreatment and the melter circuit) and affect repairs when necessary. The two equipment operators will operate the loaders which will be used to feed the quarry soil or the clay bottom to the circuit. These operators will also be available to assist the maintenance crew or assist with operations at the melter.

The melter circuit will operate 3 shifts per day, 7 days per week. One operator will be required for each shift to monitor melter operation to assure that the melter is operating at the required temperatures and production rates and that emissions are in compliance. One maintenance person will be required per shift to conduct required regular maintenance and to effect repairs when necessary; an additional maintenance person on a single shift will split his time between the pretreatment and melter circuit. One laborer will be required per shift to collect shift product samples, move product collections bins, and assist maintenance personnel as necessary.

Personal protection required for all pretreatment and process operations workers is anticipated to be at Level C or less, as dust emissions and vapors will be controlled by equipment design. During repair and maintenance tasks, increased worker protection may be required. During repair of enclosed raffinate storage bins, for example, the use of supplied air by maintenance personnel will likely be required as an added safety measure.

4.3.5.6.7 Control of Potential Dust Emissions. The vitrification process for treatment of Weldon Spring site wastes will be designed, operated, and conducted with a zero dust emission goal. Each component of the physical pretreatment and melting equipment will be totally enclosed and equipped with air filtration equipment as required. For example, the conveyance system which will transport the dewatered raffinate sludge from the dewatering facility to the physical pretreatment facility will be enclosed in an underground conduit between the facilities. The truck dumps for the soils and clay bottom material will be in enclosed buildings with exhaust hoods over the dump points. The vitrification process equipment will be installed in a building dedicated to its operation. Although the vitrification process by nature is virtually dust free, this building will be equipped with an air filtration system to add an extra measure of worker protection and to eliminate the escape of fugitive dust to the environment.

4.3.5.6.8 Fuel Requirements and Availability. The fossil fuel-heated ceramic melting technology designed by Vortec Corporation has the ability to use a variety of fuels such as coal, fuel oil, waste oil, natural gas, and combinations of these. This alternative is based on the use of natural gas as the sole fuel source for the melter. Natural gas was chosen due to its cleaner burning attributes, its availability at the site, and the lack of a requirement for storing large quantities of this fuel at the site. The estimated consumption of natural gas by the melter is 562,000 cubic feet per day and 205,312,500 cubic feet per year. The estimated maximum consumption of natural gas by the melter operating at maximum capacity is 720,000 cubic feet per day.

Discussions with Laclede Gas Company, St. Charles, Missouri, indicate that delivery of the required 1 million cubic feet or less of natural gas per day is possible. Laclede states that a pipeline could be easily extended to the Weldon Spring site, and that its capacity would be large enough to ensure continuous delivery of natural gas at the daily and annual rates required. Laclede quoted a rate of $0.00041688 per cubic feet of gas. This rate corresponds to an annual vitrification fuel cost of $86,000.

Natural gas is also required for the driers in the physical pretreatment circuits, but at a much lower demand of approximately 59×10^6 per cubic foot per year, or $24,600. Electrical costs are also estimated to be less than $30,000 per year.

4.3.5.6.9 Reduction in Waste Quantities Through Vitrification. A significant reduction in waste quantities is realized through the vitrification of selected Weldon Spring wastes. Initial waste tonnages as listed in Table 4-11, total 377,000 tons; the estimated tonnage of the vitrified product is 182,500 tons. This represents a reduction in waste tonnage of 52%. Similarly, the initial volume of these wastes is 323,400 cubic yards; the estimated volume of the vitrified product is 102,500 cubic yards. This represents a reduction in waste volume of 68%. These reductions in tonnage and volume are largely due to the removal of moisture in the waste and a reduction of the intergranular void spaces in the wastes.

4.3.5.6.10 Uncertainties. The operational uncertainties associated with this alternative are directly related to certain assumptions upon which this discussion is based. Many of the assumptions must be tested at the bench or pilot scale prior to final design of the process systems.

Physically dewatering and then physically pretreating the raffinate sludge prior to vitrification may not be the most expeditious or cost-effective method of preparing the sludge for vitrification. Future studies may indicate that simply slurrying the raffinate sludge to the melter, mixing it with contaminated soil or clay, which may or may not have been physically pretreated, may be the optimal material treatment prior to vitrification. Concerns regarding the physical treatment of the contaminated soil and clay and the associated potential for clogging in the sizing circuits may mandate the use of thermal drying units for this material. It is possible that the moisture content of some of the quarry soil is less than 20%, which may make physical pretreatment possible without drying. An advantage of pretreatment without drying is that drying of some of the soils may create some undesirable volatilization. Future bench-scale testing may indicate that physical dewatering of the raffinate sludge to 80% solids may not be achievable. For the purposes of this alternative, however, physical dewatering of the raffinate sludge and drying and size reduction is assumed for all of the waste materials.

The recycling of the off-gas treatment wastes from the primary scrubber is assumed to be included in this alternative. However, it may be determined during future studies that 100% recycling is not possible, and that a certain amount of these wastes will require separate disposal methods.

Engineering, bench, and pilot studies will be conducted prior to full-scale plant design and construction. Data from these studies are necessary to adequately determine process variables such as energy consumption, range of raffinate sludge to soil/clay bottom solids ratio which will melt to form a waste glass with the desired characteristics, minimum operating temperature required to assure adequate melting of the feed mixture, partitioning of contaminants of concern between the melt and off-gas, and the distribution of contaminants of concern in the off-gas treatment system and their recycle capacity. These studies will be performed as part of the bench- and pilot-scale testing program.

Studies will also be conducted to determine the physical parameters of the waste and pretreatment requirements prior to vitrification, such as dewatering, delumping, sizing, conveying or pneumatic transport, and storage. Additional studies will determine engineering properties of the glass produced for use in determining appropriate containment systems and placement methodologies.

4.3.6 On-Site Disposal Cell

For the vitrification and on-site disposal alternative, the disposal facility will be comprised of two separate cells, consisting of an unlined cell (compacted clay bottom) for vitrified waste and a single-lined cell for the remaining wastes. The separate-cell disposal facility concept is to place the two different waste forms (vitrified and untreated) in separate cells so that each cell will meet the requirements and regulations for the waste to be placed. The waste to be vitrified has higher levels of radioactive and chemical contamination than the remaining wastes because of the sources. The vitrified material is expected to be chemically inert but still retain its low-level radioactive characteristics. Therefore, the vitrified-waste cell, ideally, would be similar to a by-product waste disposal cell, such as those being designed and constructed for the DOE Uranium Mill Tailings Remedial Action (UMTRA) project. A lining system is not required in this type of cell, but a cover that will prevent infiltration and provide radon attenuation is required. The less stringent design would be implemented only if further testing proves the effectiveness of the treatment process. The non-vitrified waste will be less contaminated; therefore, only a single-lined leachate collection system will be necessary for the containment cell. An alternative would be to incorporate all waste within the same single-lined cell.

The various wastes and corresponding quantities requiring disposal under this alternative are shown in Table 4-13.

TABLE 4-13 Summary of Waste Quantities (Bank Cubic Yards)

1. Soil-Like Waste	479,000
2. Wastes to be Vitrified	
• Raffinate Pit Sludges	220,000
• Raffinate Pit Clay Bottom	50,000
• Quarry Soils	50,000
• WTP Residues	4,000
Subtotal	324,000
3. Rubble	224,000
Total	1,027,000

The cell designs described in this alternative provide for sufficient capacity to accommodate the total waste volume removed from all site source areas. This capacity will be necessary to ensure that the design cells will be able to accommodate a contingency, as well as potential additional wastes from activities involving the quarry residuals, Femme Osage Slough, and Southeast Drainage.

4.3.6.1 Waste Descriptions and Assumptions. The two separate cells for vitrified and untreated waste will consist of one unlined cell similar to an UMTRA-type to accommodate the vitrified material (approximately 113,000 cubic yards after vitrification) and one disposal cell with a single-lined leachate collection system for the remaining soil-like, less-contaminated waste and rubble, totalling approximately 773,000 cubic yards.

Under this alternative, approximately 102,500 cubic yards of vitrified waste material will be converted from the original bank volume of 324,000 cubic yards of sludges and soils. Applying a 10% contingency factor yields a total vitrified volume of 113,000 cubic yards for cell capacity sizing. The waste quantities are summarized in Table 4-14.

TABLE 4-14 Estimated Quantities for Various Earthwork Components for Separate Cells

1. Wastes to be relocated (Bank Volume)	Soil-like waste	479,000	yd^3
	Vitrified waste	324,000	yd^3
	Rubble	224,000	yd^3
	Total	1,027,000	yd^3

Table 4-14 Estimated Quantities for Various Earthwork Components for Separate Cells (Continued)

2. Wastes In-Place (including 10% contingency factor)	Soil-like waste	527,000	yd^3
	Vitrified waste	113,000	yd^3
	Rubble	246,000	yd^3
	Total	886,000	yd^3
3. Cell Capacity	For Vitrified-Waste Cell	113,000	yd^3
	For Non-Vitrified Waste, Single-lined Cell	773,000	yd^3
4. Vitrified Cell			
Foundation	Area	58,000	yd^2
	Excavation	67,000	yd^3
	Fill	92,000	yd^3
Cover	6-inch Filter	4,000	yd^3
	4-foot Clay Cover	33,000	yd^3
	3-foot Frost Protection Layer	24,000	yd^3
	1-foot Choke Rock Layer	20,000	yd^3
Total Vitrified Cell Cover Area		60,000	yd^2
5. Single-Lined Cell Foundation	Area	146,000	yd^2
	Excavation	125,000	yd^3
	Fill	125,000	yd^3
	3-foot Clay Liner	146,000	yd^3
	FML	146,000	yd^2
	1-foot LCRS	49,000	yd^3
	6-inch Filter	24,000	yd^3
	6-inch-Dia. Pipe	7,400	lineal ft
	126-ft^3 Concrete Sump	16	Unit
Cover Top Slope	4-foot Clay Cover	16,000	yd^3
	FML	12,000	yd^2
	6-inch Filter	2,000	yd^3
	1-foot Drain	4,000	yd^3
	6-inch Filter	2,000	yd^3
	2-inch Frost Protection Layer	8,000	yd^3
	1-foot Choke Rock Layer	4,000	yd^3
Side Slope	4-foot Clay Cover	182,000	yd^3
	3-foot Frost Protection Layer	136,000	yd^3
	FML	136,000	yd^2
	6-inch Filter	23,000	yd^3
	1-foot Riprap	45,000	yd^3
	6-inch Choke Rock	23,000	yd^3
Total Single-Lined Cell Cover Area		148,000	yd^2

The vitrified product will be transported from the treatment facility to the cell via haul trucks. The vitrified material will be a fritted product consisting of ⅛-inch- to possibly ¼-inch-diameter glassy pellets that are primarily composed of quartz. The unit weight for this material is assumed to be 1.78 tons per cubic yards. The 125 tons-per-day production rate for the vitrification process corresponds to a placement rate of 142 cubic yards per day on a 5-day placement operation work week, 20 days per month, with 9 operating months per year, or 253 tons per day.

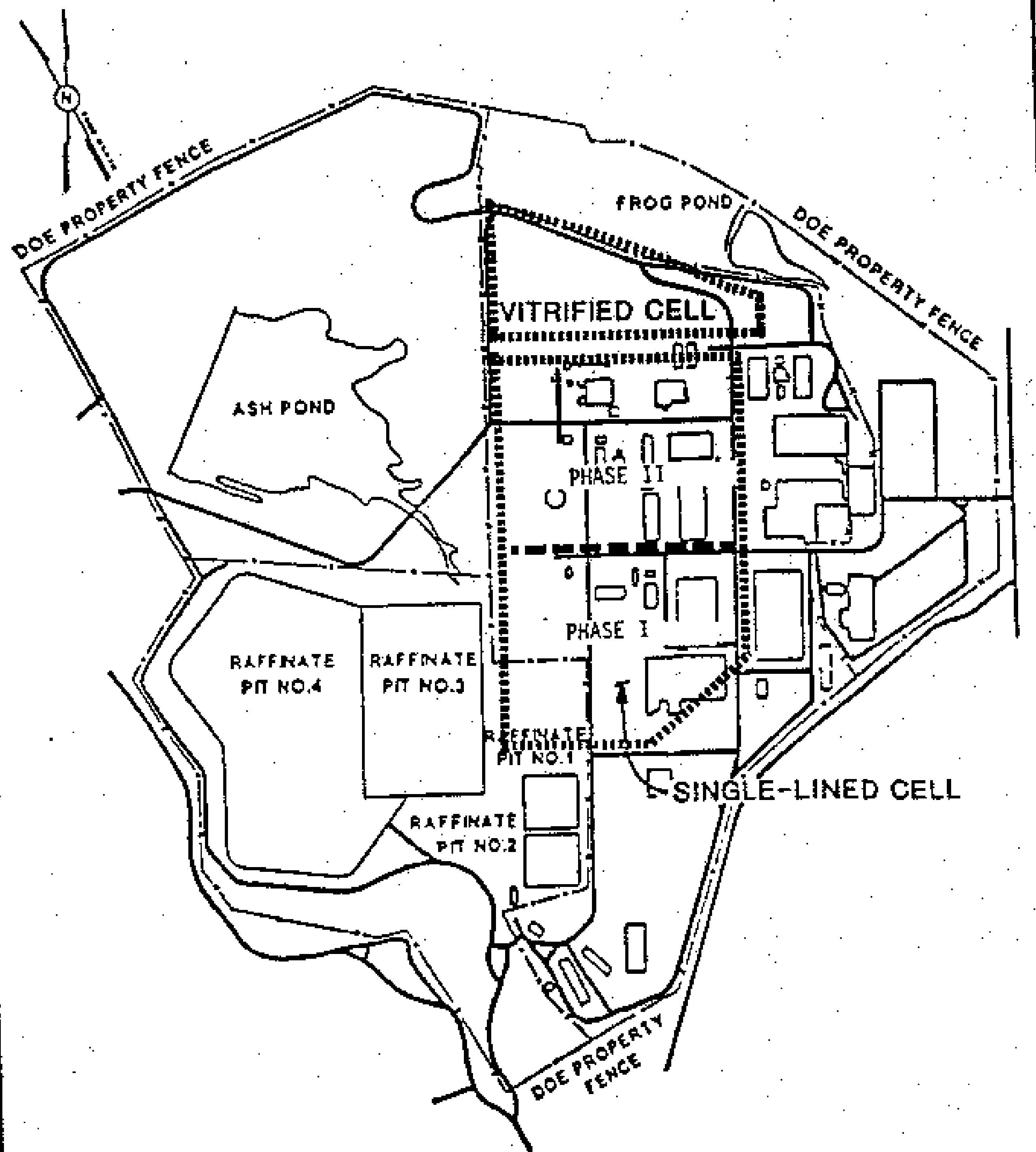
The vitrified material will be cohesionless due to its particulate nature and smooth glassy surface. A porosity of 20% is assumed when the vitrified material, without binder, is placed in the cell. A binder, such as the on-site clayey materials, will be added to facilitate compaction. Approximately 15% binder by volume is assumed to be adequate for the vitrified material to be bound together as a coherent unit for construction mobility and strength purposes. The addition of the binder will not create additional in-place volumes because the vitrified material by itself is assumed to have an in-place porosity of 20%.

The remaining waste (703,000 yd^3) which is not vitrified will consist of approximately 479,000 cubic yards of soil-like waste and 224,000 cubic yards of rubble. Applying a contingency factor of 10% will yield approximately 527,000 cubic yards of soil-like waste and 246,000 cubic yards of rubble for a total of 773,000 cubic yards for placement in a cell with a single-lined leachate collection system.

4.3.6.2 Conceptual Cell Design Description and Assumptions. The vitrified-waste cell will involve both below-grade and above-grade construction. A rough conceptual layout and typical section are shown in Figures 4-9 and 4-10, respectively. The cell will be below-grade with 2.5 to 1 horizontal to vertical (H:V) side slopes. An earthen embankment will be constructed using the excavated material to attain the cell's design height of approximately 35 feet (from the lowest ground surface to the top of the cover). Surplus excavation material that is unsuitable for embankment construction will be stockpiled on site for future site grading use. The inside slope of the embankment fill will be 2.5:1 (H:V); the outside slope 3:1 (H:V).

The vitrified-waste cell design will feature a cover consisting (in ascending order from the vitrified material contact) of a filter layer to maintain waste separation from the infiltration/radon barrier, an infiltration/radon attenuation barrier, a frost protection layer and an erosion protection (riprap and topsoil with grass) layer.

The non-vitrified wastes will most likely consist of soil-like, less contaminated waste and rubble. These wastes will be encapsulated in a cell with a single-lined leachate collection and removal system (LCRS) and a cover system.



NOTE:
1. Construction starts at south.

LEGEND:

▪▪▪▪▪▪▪▪▪ TOE OF CELL

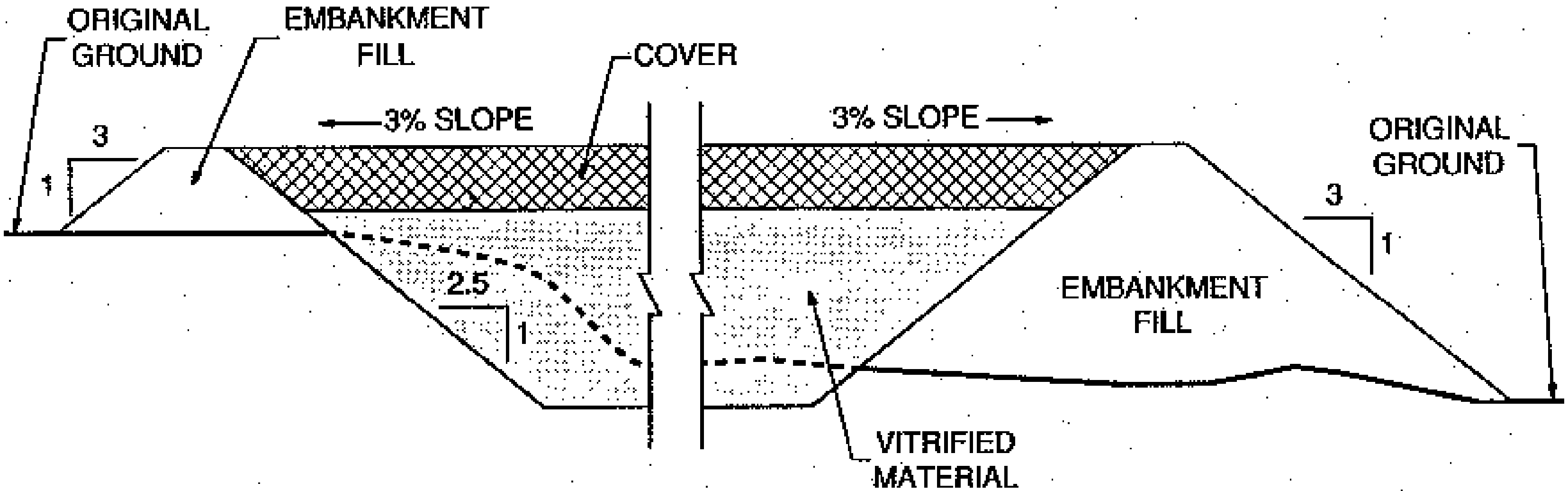
0 600' 1000'
SCALE

CONCEPTUAL LAYOUT OF DISPOSAL FACILITY

VITRIFIED CELL & SINGLE-LINED CELL

FIGURE 4-9

REPORT NO. 3840-TM-790-01		DRAWING NO.
ORIGINATOR ECT	DRAWN BY ECT	DATE 4/12/91



NOT TO SCALE

VITRIFIED WASTE CELL
TYPICAL SECTION

FIGURE 4-10

REPORT NO.:		EXHIBIT NO.: A/PI/004/0192
ORIGINATOR: BLG	DRAWN BY: GLN	DATE: 1/92

The single-lined LCRS will include a composite liner, consisting of a flexible membrane liner and a compacted clay layer, a 6-inch-diameter perforated collection drain pipe network, and a granular soil layer to collect the leachate. A filter zone will be required between the granular soil layer and the wastes placed above.

The cover on the top slopes will consist of (in ascending order from the waste contact) an infiltration/radon attenuation barrier, a flexible membrane liner, a filter protected drain layer, a frost protection layer, and an erosion protection (riprap) layer. The riprap layer will be choked with topsoil and fine-grained soil for grass growth. The cell's side slope cover will consist of an infiltration/radon attenuation barrier, a frost-protection layer, an FML and a filter-protected riprap layer with a choked rock surface (identical to the top slope choked rock surface) to support grass growth. The height for the single-lined cell will be a maximum of 74 feet above the ground surface.

An estimate of the quantities required for each cell component is shown in Table 3-11. All fill materials and wastes will be compacted.

4.3.6.3 Construction Operation Requirements. The work described below is dependent on the rate that wastes are available for placement in the cell. Approximately 377,000 cubic yards of soil and 203,000 cubic yards of rubble will be placed in the single-lined cell and 102,500 cubic yards of vitrified material will be placed in the unlined vitrified-waste cell. To accommodate the Weldon Spring wastes described previously, placement of waste in the vitrified cell and within the single-lined cell is scheduled to require 4 years and 5 years, respectively, with the cells filled simultaneously. To accommodate placement of materials generated by site closure and vicinity property remediation, the single-lined cell will be open for the 5-year period.

Windblown particulates from the fine-grained materials involved in construction and waste placement will be controlled through dust suppression methods. Periodic spraying with water and/or dust suppressants will be used to control windblown matter while the cell is being constructed. When a section of the radon/infiltration barrier is completed, the surface will be sealed with a steel-wheeled roller, and if it is to be left unattended for a period of a month or more, a more permanent control measure, such as placing a flexible membrane over the fine-grained materials, will be used. Another means to minimize transport of contaminated particulates to the environment will be by placing clean cover material on a selected side of the cell as the waste material is being placed and encapsulating the cell phases as they are completed.

Radon will be emitted from the waste material placed in the cell. Radioactive emissions in the air will be monitored during construction and operation of the disposal facility. If excessive radon gas levels are reached, as discussed in previous sections, engineering controls will be implemented to minimize public and worker exposure.

4.3.6.3.1 Single-lined Cell. The construction operation requirements for the single-lined cell for untreated waste are essentially the same as the requirements for the combination cell described in Section 4.2.6.3, with the following exceptions:

1. The cell will be constructed in 2 phases only, with the Phase 1 area in the southern portion and the Phase 2 area in the northern portion.

2. Final adjustment to accommodate the actual volume of waste placed will be made in the Phase 2 area.

3. The entire disposal cell will be constructed in about 6.5 years.

4. A LCRS with a composite liner will be constructed.

5. Soil-like waste will be placed adjacent to and around the rubble, probably requiring some hand compaction by laborers.

- **Foundation.** Construction work will start at the original ground or building foundation surfaces and any excavation will be backfilled to this level. Clearing and grubbing, removal of underground piping, and foundations, excavation of contaminate soils, and backfilling of deep excavations are described in Sections 4.2.1 and 4.2.2.

  Approximately 125,000 cubic yards of excavation and 125,000 cubic yards of fill will be required to construct foundation subgrade of the cell depicted in Figure 4-8. The excavation and fill will be accomplished over a period of 32 crew days at a rate of 500 cubic yards per hour by a 12.5-man crew using two scrapers, a Raygo 600 compactor, a D-9 dozer, a D-8 dozer, a 4-inch pump (quarter time), a grader, a water truck (half time), a disk harrow, and a 1-cubic-yard backhoe.

  The next activity will be scarifying and compacting the finished subgrade (146,000 square yards) prior to placement of the leachate collection system materials. This activity will be accomplished at a rate of 2,500 square yards per hour by a crew of five using a crawler tractor with a disk harrow followed by a Raygo 400 compactor. If necessary, a water truck will be used to add water to achieve the specified moisture content. Eight crew days will be required for the foundation preparation.

A 3-foot-thick clay liner totaling 146,000 cubic yards will be placed in the cell. This material will be delivered from an off-site borrow area (within 5 miles) and placed at a rate of 80 cubic yards per hour by a 17-man crew using nine 10-cubic-yard end-dump highway haul trucks, two D-6 dozers, a Raygo 400 compactor, a disk harrow, a 988 loader, a 4-inch pump (quarter time), a grader to fine grade and maintain haul roads, and a water wagon to maintain specified moisture content and to suppress dust. This operation will require 229 work days.

Approximately 146,000 square yards of FML will be placed over the clay layer by a crew of 8 using a tractor to unroll the material. Seams will be bonded by the placement crew and tested to assure that they meet quality control requirements. Placement will be on a continuous basis over half of the area at a rate of 20,000 square feet per day. The crew will require 66 work days to install the liner.

A 1-foot-thick LCRS layer will then be placed. It is assumed that the 49,000 cubic yards of gravelly drain type material required will be purchased from a local commercial source and delivered to the job site. The material will be placed at a rate of 33 cubic yards per hour by a crew of six using a 2-cubic-yard loader, a smooth-drum vibrating roller, a grader, a water truck, and a 4-inch pump (quarter time). Embedded in this layer will be a network of 6-inch-diameter perforated HDPE pipes that will be used to direct leachate to sumps or manholes located immediately outside the toe of the cell. This network will be placed by a crew of 6 at a rate of 50 feet per hour. Approximately 7,400 feet of pipe will be placed during a 19-work-day duration, concurrently with the gravel placement. Installation of the gravel will be accomplished in 186 work days.

The LCRS will have 16 collection sumps or manholes. Installation of these elements will be performed by a crew of 6 with a CAT 235 backhoe, a flatbed truck, and hand compactors (half time). Installation is estimated at 13 crew hours per sump for a period of 28 crew days.

A 6-inch-thick layer of filter sand material (approximately 24,000 yd^3) will be placed on the top of the double LCRS over a period of 120 crew days. Filter sand delivered to the placement site will be spread and compacted by a 6-man crew using a D-6 dozer, a Raygo 400 smooth-drum compactor, a 2-cubic-yard loader, a water truck, and a 4-inch pump (quarter time) at a rate of 25 cubic yards an hour.

- **Waste Placement.** Two basic forms of waste material, (377,000 in-place yd^3 of soil-like materials and 203,000 yd^3 of rubble), will be placed in the disposal cell. The soil-like material will be placed around and on top of the individual rubble components. Spreading and placement will be performed as described for Alternative 6A in Section 4.2.6.

- **Cover: Top Slope.** A 4-foot-thick clay cover totaling 16,000 cubic yards will be placed over the treated waste in the cell. The material will be delivered from an off-site borrow source (within 5 miles) at a rate of 80 cubic yards per hour by a 17-man crew using a 988 loader, nine 10-cubic-yard end-dump highway haul trucks, two D-6 dozers, a Raygo 400 compactor, a disk harrow, a grader to fine grade and maintain haul roads, and a water wagon to maintain moisture content within specified limits and control dust. This operation will require 25 crew days.

  A 12,000-square-yard FML will be placed over the clay layer by a crew of 8 using a tractor to unroll the material. Seams will be bonded by the placement crew and tested to assure that they meet quality control requirements. Placement will require 6 work days at a rate of 20,000 square feet per day.

  The next cover component consists of a 6-inch-thick layer (2,000 yd^3) of filter material, followed by a 1-foot-thick layer (4,000 yd^3) of drain rock, topped by a 6-inch-thick layer (2,000 yd^3) of filter material. All of these materials will be purchased commercially and delivered to the job site. The materials will be spread by a 6-man crew using a D-6 dozer, a grader, a Raygo 400 smooth-drum compactor, a 3-cubic-yard front-end loader, and a water truck at a rate of 25 cubic yards per hour. Completion of the filter system will require 40 work days.

  A 2-foot-thick frost protection layer (8,000 yd^3) will be constructed by a 17-man crew using a 988 loader, two D-6 dozers, a Raygo 400 compactor, a disk harrow, nine 10-cubic-yard end-dump trucks, a grader to fine grade, and a water wagon to maintain the moisture content of the material and control dust at a rate of 80 cubic yards per hour during a 13-day work period.

A 1-foot-thick riprap layer with choked rock surface will be placed at the top of the cell. Approximately 4,000 cubic yards of material will be delivered to the site from a local commercial source by truck. It will be spread at a rate of 20 cubic yards per hour by a crew of six using a D-6 dozer, a 2-cubic-yard front-end loader, a 1-cubic-yard backhoe, and a water truck over a 25-work-day period. The cell cover surface will be seeded with grass or covered with sod to reduce infiltration.

- **Cover: Side Slope.** A 4-foot-thick clay cover layer (182,000 yd^3), followed by a 3-foot-thick frost protection layer (136,000 yd^3), will be placed over the tailings material on the side slopes. The material will be delivered from the same off-site borrow source as for the top slope cover material. The operating rate, equipment, and labor will be the same as required for the top slope. These zones will be raised above the waste materials and will be constructed concurrently with waste placement. Total crew days required for placement of both cover components is 497 days.

  A 136,000-square-yard FML will be placed on the frost protection layer by a crew of 8 using a tractor to unroll the material. Seams will be bonded by the placement crew and tested to assure that they meet quality control requirements. Placement over the frost protection zone is anticipated to occur when the side slope has reached its maximum height. Placement at a rate of 15,000 square feet per day, due to side slope conditions, will require 82 crew days.

  The next side slope layer consists of 6 inches (23,000 yd^3) of filter rock, followed by 1-foot layer (45,000 yd^3) of riprap, topped by 6 inches (23,000 yd^3) of choke rock. All of these materials will be purchased commercially and delivered to the job site by trucks and will be compacted using the crews and production rates detailed for the Alternative 6A cover side slopes in Section 4.2.6. Work crew days of 115, 188, and 144, respectively, will be required for each of these components.

4.3.6.3.2 Vitrified-Waste Cell. The construction operation for the vitrified-waste cell will require about 5.5 years and will be performed in three phases as described in the following sequence:

1. Phase I — Clearing and grubbing of the cell area, removal of underground piping and foundations, excavation of contaminated soils, and backfilling of deep excavations as discussed in Sections 4.2.1 and 4.2.2.

2. Phase I — Excavation of the foundation soil to design grade.

3. Phase I — Construction of the vitrified-waste cell embankments to full height.

4. Phase II — Placement of vitrified material in the cell.

5. Phase III — Construction of cover system and erosion protection system for top and side slopes.

- **Foundation.** Construction work will start at the original ground or building foundation surfaces, assuming that any excavations will have been backfilled to this level. The removal of contaminated materials within the area of the vitrified waste cell will be completed prior to initiating the cell construction.

  Following clearing and grubbing, 67,000 cubic yards of foundation excavation will be accomplished at a rate of 500 cubic yards per hour by a 15-man crew using 4 scrapers, a D-9 dozer, a 4-inch pump (quarter time), a grader, a disk harrow, a water truck, and a Raygo 600 compactor over a 17-day work period. Cell embankment construction will use 55,000 cubic yards of material from foundation excavation to construct perimeter embankments. The remaining 37,000 cubic yards of material required for embankment construction will be hauled from a nearby on-site borrow or stockpile area and placed at a rate of 80 cubic yards per hour by a 17-man crew using a 988 loader, nine 10-cubic-yard end-dump trucks, two D-6 dozers, a Raygo 400 compactor, a disk harrow, and a grader. A water truck will also be used periodically for moisture control and dust suppression. The operation will require 58 crew days.

- **Vitrified Material Placement.** The work described below is dependent upon the rate that vitrified material is provided and delivered for placement in the disposal cell. Approximately 102,500 cubic yards of vitrified material will be placed in the cell over a 4-year period.

The vitrified material (⅛-inch- to ¼-inch-diameter, uniformly graded, glass-like beads) will be mixed with, 15% by volume (15,400 yd^3), native clay delivered to stockpile from off-site borrow. To complete the placement of the vitrified material during the planned 4-year operation (9-month-year, 20-day-month work schedule), the vitrified material will be delivered to the cell at an average rate of approximately 17.8 cubic yards per hour on an 8-hour basis. Delivery of 15,300 cubic yards of binder to stockpile from off-site borrow will be performed over a 24-work-day period at a rate of 80 cubic yards per hour by a 16-man crew using a 988 loader, nine 10-cubic-yard end-dump trucks, two D-6 dozers, a water truck, and a grader.

The 142 cubic yards per day of vitrified material and the clay will be delivered over a 720-day period at an average rate of approximately 20 cubic yards per hour. Spreading and compacting will be performed by a 2-man crew using a D-6 dozer (half time) and a vibrating compactor (half time).

- **Cover.** A 6-inch-thick filter layer will be placed on the compacted vitrified material in the cell. The material (4,000 yd^3) will be delivered to the site from a local commercial source. It will be spread and compacted by a crew of 6 using a D-6 dozer, a 3-cubic-yard front-end loader, a water truck, a grader, and a Raygo 400 smooth-drum compactor at a rate of 25 cubic yards per hour over a 20-work-day period.

  A 4-foot-thick clay cover totaling 33,000 cubic yards will be placed over the filter layer. The clay for the cover will be delivered from an off-site borrow source (within 5 miles) and placed by a 17-man crew in 52 work days at a rate of 80 cubic yards per hour using a 988 loader, nine 10-cubic-yard end-dump trucks, two D-6 dozers, a Raygo 400 compactor, a disk harrow, a grader, and a water wagon.

  A 3-foot-thick frost protection layer (24,000 yd^3), followed by a 1-foot-thick layer of choke rock (8,000 yd^3), will be placed over the clay. The frost protection layer material will be hauled from an off-site borrow at a rate of 80 cubic yards per hour by the same crew described above for the cover. Thirty-eight crew days will be required. The choke rock will be delivered to the placement area and spread at a rate of 20 cubic yards per hour by a 6-man crew using a D-6 dozer, a 2-cubic-yard loader, a 1-cubic-yard backhoe, and a water truck over a 50-work-day period. The cell surface will be seeded with grass or sod placed to reduce infiltration.

4.3.7 Facilities Closure

These activities will be performed as described for Alternative 6A in Section 4.2.7.

4.3.8 Site Regrading

The site will be regraded as described in Section 4.2.8 for Alternative 6A.

4.4 Alternative 7B - Removal, Vitrification, and Off-Site Disposal at Clive, Utah

For this alternative, contaminated material will be processed at an on-site vitrification treatment facility and transported off-site for disposal.

4.4.1 Site Preparation

Site preparation will be accomplished as described for Alternative 6A in Section 4.2.1.

4.4.2 Excavation and Transportation of Waste Materials

Excavation and transport of Weldon Spring wastes will be accomplished in essentially the same manner under this alternative as described for Alternative 7A in Section 4.3.2. An exception will be that material designated for transport to an on-site disposal cell will be loaded into containers at the treatment facility or hauled to a temporary storage area for subsequent loading, then transported to a staging area for off-site transport. The raffinate sludge will also require dewatering as described in Section 4.3.5 for Alternative 7A.

4.4.3 Volume Reduction

Under this alternative, the size reduction methods and procedures will be the same as described in Section 4.2.3 for Alternative 6A, with the following exceptions:

1. The material processed in the volume reduction facility will be placed in containers which will be hauled to Clive, Utah, for disposal.

2. The VRF building design will also include provisions for receiving four large containers mounted on a modified rail car. Therefore, in addition to the VRF equipment listed in Table 4-5, a 20-hp car puller will be required at a unit cost

of $45,000. The car puller will move the rail car under the feed point for crushed and sheared material. As the containers are filled, the rail car will be moved as required, to ensure a uniform and balanced load. When the containers are loaded to their 28-ton capacity, lids will be placed in position, and the containers will be sealed and decontaminated. The doors on the building will be opened, the rail cars pulled out, and the containers removed. Empty containers will be placed on the rail car which will be pulled back into the building where the containers will again be positioned and filled.

4.4.4 Metals Decontamination

These activities may be accomplished in the same manner described in Section 4.2.4 for Alternative 6A.

4.4.5 Vitrification

The dewatered raffinate pit sludge, raffinate pit clay bottom material, quarry soils, and water treatment plant residues will be vitrified in a fossil fuel-heated ceramic melter as described in Section 4.3.5 for Alternative 7A.

4.4.6 Off-Site Disposal at Clive, Utah

The following discussion addresses the transport of Weldon Spring soils, sludges, building rubble, and other debris to the Envirocare Inc. facility at Clive, Utah. Three types of materials will be transported:

1. Vitrified soils and sludges (Table 4-15).

2. Contaminated soils (Table 4-16).

3. Size-reduced rubble and other materials (Table 4-17).

The volumes shown in these tables do not include volumes related to the quarry residuals, Femme Osage Slough or the Southeast Drainage.

of $45,000. The car puller will move the rail car under the feed point for crushed and sheared material. As the containers are filled, the rail car will be moved as required, to ensure a uniform and balanced load. When the containers are loaded to their 28-ton capacity, lids will be placed in position, and the containers will be sealed and decontaminated. The doors on the building will be opened, the rail cars pulled out, and the containers removed. Empty containers will be placed on the rail car which will be pulled back into the building where the containers will again be positioned and filled.

4.4.4 Metals Decontamination

These activities may be accomplished in the same manner described in Section 4.2.4 for Alternative 6A.

4.4.5 Vitrification

The dewatered raffinate pit sludge, raffinate pit clay bottom material, quarry soils, and water treatment plant residues will be vitrified in a fossil fuel-heated ceramic melter as described in Section 4.3.5 for Alternative 7A.

4.4.6 Off-Site Disposal at Clive, Utah

The following discussion addresses the transport of Weldon Spring soils, sludges, building rubble, and other debris to the Envirocare Inc. facility at Clive, Utah. Three types of materials will be transported:

1. Vitrified soils and sludges (Table 4-15).

2. Contaminated soils (Table 4-16).

3. Size-reduced rubble and other materials (Table 4-17).

The volumes shown in these tables do not include volumes related to the quarry residuals, Femme Osage Slough or the Southeast Drainage.

TABLE 4-15 Off-Site Disposal of Vitrified Material

Material	Vitrified Weight Cubic Yards	Tons
Raffinate Pit Soils	34,150	60,800
Raffinate Pit Sludge	33,700	60,000
Quarry Bulk Waste	34,150	60,800
WTP Residues and Drummed Solid Waste	500	900
TOTAL	102,500	182,500

[a] Data is from Waste Quantities Quarterly Report: 4/1/91 - 6/30/91 (MKF and JEG 1991b).
[b] Only 50,000 cubic yards of the raffinate pit soils will be vitrified (greater than 300 pCi/g uranium-238).

TABLE 4-16 Off-Site Disposal of Untreated Material

Material	Volume Yd³	Weight Tons
Raffinate Pit Soils	103,500	157,320
Ash Pond Soils & Sediment	8,200	12,460
Frog Pond Soils & Sediment	7,000	10,640
North Dump Soils	7,600	11,550
South Dump Soils	16,900	25,690
TSA Soils	4,100	6,320
Site Water Treatment Plant Area Soils	1,700	2,580
Soils Around Chemical Plant Buildings	26,400	40,130
Soils Beneath Chemical Plant Buildings and Open Areas	59,000	89,680
Lakes 34, 34, and 36 Sediments	20,000	30,400
Chipped Wood and Vegetation	30,550	19,310
TSA Sediments and Soil	6,100	9,270
Army Vicinity Properties 1, 2 & 3 Soils	1,400	2,130
Busch Vicinity Properties 3, 4 & 5 Soils	500	760

TABLE 4-16 Off-Site Disposal of Untreated Material (Continued)

Material	Volume Yd³	Weight Tons
Army Vicinity Properties 5 & 6 Soils	1,700	2,580
Total Roads & Embankments	76,930	116,930
Used PPE	5,000	920
TOTAL	376,680	538,670

TABLE 4-17 Off-Site Disposal of Size-Reduced Building Materials

Material	Converted Volume Yd³	Weight Tons
Quarry Bulk Metal	10,500	69,460
Quarry Bulk Rock/Concrete	30,200	61,910
Site WTP (Closure)	400	810
TSA Foundation (Closure)	22,000	45,100
Raffinate Pit Rubble	500	3,310
MSA Foundation (Closure)	14,500	26,250
Treatment Facility (Closure)	900	3,890
Volume Reduction Facility (Closure)	500	2,160
Roofing, Siding, and Flooring	5,100	10,902
Friable Asbestos	4,700	2,929
Masonry Block	7,300	5,519
Slab Deck and Foundation	51,500	104,316
Debris	300	398
Conduit and Piping	2,400	3,925
HVAC Ductwork	100	333
Tanks	6,500	1,304

TABLE 4-17 Off-Site Disposal of Size-Reduced Building Materials (Continued)

Material		Converted Volume Yd³	Weight Tons
Misc. Equipment		40,800	8,162
Underground Piping		1,300	1,734
Furniture & Solid Wood		2,300	924
Siding (Aluminium & Steel)		100	462
Structural Steel and RR Rails		1,100	7,645
	TOTAL	203,000	361,433

The vitrified material will be produced from raffinate pit sludges, raffinate pit clay bottom material, and quarry soils at a rate of 125 tons/day, 3 shifts/day, 7 days/week, 12 months/year over a 4-year period. The sized rubble will be generated at variable rates with a 320-ton-per-day average on a single shift, 5-day-per-week basis, depending on the materials being processed and upon the rate of removal. Not all rubble will require volume reduction. Gravel from the MSA and asphalt and gravel from the TSA, heavy metal shapes, and ACM, as well as rubble from demolition of the volume reduction facility and the water treatment plant at the conclusion of waste removal, will not be processed. Approximately 122,900 cubic yards of material will be processed. The contaminated soils staged at the Ash Pond spoils pile and at the TSA will be transported at a rate that will even out any variation in the production of vitrified or sized materials. The average rate will be 483 tons per day on a single-shift, 5-day-per-week basis. All of the materials will be transported over a 4- to 5-year period.

Containers will be filled with vitrified waste and size-reduced rubble at the vitrification facility, at the volume reduction facility, and at the site of removal operations. The 377,000 cubic yards of contaminated soil from the TSA, the Ash Pond spoils pile, and from decommissioning sites will be transported to a transfer station for container decontamination and transloading. The transfer station will be located in the area to the east of the Ash Pond spoils pile. The Ash Pond spoils area will be used as surge storage for contaminated soils transloading to permit excavation to proceed at optimum rates and schedules and to allow a more uniform rate of removal from the site. At transfer stations at the volume reduction facility and the vitrification plant, containers will also be closed, externally decontaminated, loaded onto a lowboy trailer, and hauled from the site by truck to a railroad siding at Wentzville, Missouri. The containers will be either staged at the Wentzville siding or transferred immediately to rail flatcars. Trains of 25 cars, 3 containers per car, will be hauled to Clive, Utah, which is accessible by a rail siding where the containers will be transferred to a truck and dumped directly into the disposal cell. The containers will be externally decontaminated, placed on the rail flatcar, and transported back to the Wentzville siding and staging area for off-loading and placement on trucks for the return to the plant site transfer stations.

4.4.6.1 Containers. The containers selected for calculating the cost of transporting the Weldon Spring wastes are 8 x 8 x 10 feet and can contain 23.7 cubic yards. They are designed to be handled by standard intermodal container equipment and fit on railroad flatcars designed for the containers. These containers will be similar to those used for hauling the UMTRA project waste from Grand Junction, Colorado, except that the containers proposed for the Weldon Spring wastes will be covered and will be approximately one-half the size. The covers will prevent dust emissions during transportation to the waste disposal site. These containers were selected due to their commercial availability and proven transport capability, even though they have excess capacity.

A translift will be used to move containers and place them on the lowboy trailers or the railroad flatcars. The lowboy trailers and railroad flatcars will be fitted with brackets which hold the containers in place.

The product densities will vary from 1.78 tons per cubic yard for the vitrified product to 1.35 tons per cubic yard for loose soil and rubble. The container contents will be limited to 28 tons by highway load restrictions of 40 tons gross vehicle weight, which restricts the volume loading of the containers to 16 cubic yards for the vitrified product and 21 cubic yards for soil and rubble.

The containers fabricated and tested for the UMTRA Grand Junction site cost $7,700 each. A similar container with a cover will cost $6,000, based on the relative quantities of steel required for a 23.7-cubic-yard unit. Similar containers, new and reconstructed, can be purchased for as little as $2,200, but they are not designed for transporting contaminated waste soils and have not been tested. Approximately 525 containers will be required for the project. Four 25-car trains (75 containers each) will be en route at a given time, based upon an 8-day train cycle, with 250 containers distributed among the various staging areas to assure uninterrupted transport of material from the site to the train siding at Clive. The containers represent less than 5% of the off-site disposal costs.

4.4.6.2 Loading. A staging and loading area will be constructed to the east of the South Dump extending into the area of the projected disposal cell footprint, since the disposal cell will not be constructed if off-site waste disposal is the selected alternative. A 10-acre area has been identified for construction materials storage and includes roads, prepared sub-base, and a gravel surface. A similar area would be prepared for access to the transfer station which will consist of a 6-inch-thick, 25,000-square-foot concrete slab for container transloading, storage, and decontamination. Transfer stations with 6-inch 5,000-square-foot and 10,000-square-foot concrete slabs will also be provided at the volume reduction facility and at the vitrification plant, respectively. Both the volume reduction facility and vitrification plant will be equipped with car pullers and cars to move containers while loading. Containers will be closed and decontaminated prior to transfer to the trucks. Sufficient capacity will be provided at the vitrification plant to accommodate weekend production.

Container loading of soil and decommissioning rubble will be accomplished with a 3-cubic-yard end-loader. Containers will then be loaded onto a low-boy truck for shuttle to the transfer station. At the vitrification plant and at the volume reduction facility, the containers will be transloaded on the transfer station pads. A maximum of 37 containers of material per day will be transported to Wentzville on a 5-day-per-week, single-shift basis. Seven low-boy transporters will be required during the peak performance period, based upon a 72-minute cycle time. The trucks will make a maximum of 6 trips per day. Weldon Spring site personnel will man four translifts; two at the site, one at the Wentzville siding, and one at the disposal site.

Loading at the volume reduction facility during the four 3-month winter shutdown periods will be accomplished using a 3-cubic-yard loader to shuttle waste from the MSA for container loading.

The use of a contaminated stockpile for transloading from trucks to containers will require a 3-man crew consisting of a dozer operator and 2 maintenance laborers with a D-6 dozer. This crew will receive the soils removed during waste excavation, will place and compact stockpiles, and will maintain the stockpile cover. Dust control methods will include covering material stockpiles and spraying water from trucks. All containers will be closed to eliminate dust generation during transport.

The surge pile maintenance and the shuttle of containers to the transfer pads, the closing and decontamination of the containers, the transloading of the containers at the transfer pads, transport of the containers to and from the Wentzville siding, and subsequent transfer to and from the railcar at the siding and at the disposal facility will be performed using the crew and equipment cited in Tables 4-18, 4-19, and 4-20 operating on a single shift, 5 days/week, 52 weeks/year over a 4.75 year period. The translift operator, the loader operator, and the shuttle lowboy driver working in contaminated zones, as well as the two decontamination laborers, the stockpile maintenance crew, and the winter loading crew at the volume reduction facility will be in Level C personal protective equipment (PPE), requiring four changes in Tyvek suits, four pairs of gloves, and two respirator cartridges per day per person, along with one pair of boots and one half-face cartridge respirator per person. The translift operators at the transfer pads, at the train siding, and at the disposal facility, as well as the lowboy transport drivers, the grader operator, the water truck driver, and the two laborers at the siding, will be in Level D PPE.

TABLE 4-18Container Handling Operation Equipment Manpower Requirements (1,140 work days)

Equipment	1 3-cu-yd loader 4 Translifts 6 Lowboy trucks 1 Water truck 3 Hotseys 1 Car puller (24 hours, 7 days) 1 Grader
Labor	2 Foremen 6 Operators 4 Laborers 7.7 Teamsters 1 Documentation control 0.5 Safety inspector

TABLE 4-19 Surge Pile Maintenance Equipment and Manpower Requirements (1,140 work days)

Equipment	1 D-6 dozer

TABLE 4-19 Surge Pile Maintenance Equipment and Manpower Requirements (1,140 work days) (Continued)

Labor	1 Operator 2 Laborers

TABLE 4-20 Winter Loading at the Volume Reduction Facility (240 work days)

Equipment	1 3-yd³ front-end loader 1 Car carrier and puller
Labor	2 Operators 1 Laborer

4.4.6.3 Truck Transportation. The filled containers will be trucked from the Weldon Spring site, along the route shown in Figure 4-11, to a railroad siding (Figure 4-12) to be constructed or leased in Wentzville, Missouri. At the siding, containers will be translifted from the lowboy truck trailers to the flatbed railcars for shipment from Wentzville to the disposal site. During the peak performance period, the seven trucks will make a maximum of 6 trips per day.

4.4.6.4 Railroad Transportation. Rail transport from Wentzville to the Clive, Utah, disposal site will be provided by the Union Pacific Railroad which serves both the St. Louis area and the Salt Lake City area (for the Clive site). A potential Union Pacific rail route is shown in Figure 4-13, and is described in Section 4.4.6.6.

A railroad siding will be constructed near Wentzville, Missouri, which will consist of two 2,000-foot tracks with a 400-foot approach and exit (total 5,600 feet), 4 switches, and 8 crossings. The siding will occupy 11 acres which will be cleared and graded before the siding is constructed. The siding will include two 6-inch-thick concrete transfer pads, totalling 125,000 square feet, and gravel approach area. Dust suppression during construction will be achieved using water sprayed from trucks and suppressant chemicals. The concrete transfer pad will also minimize dust generation during operations. The rail bed will be covered with gravel. Other disturbed areas will be planted with grass seed. The siding construction will require approximately six weeks and cost approximately $2,285,000. The Union Pacific has flatcars that accept the intermodal containers described in Section 4.4.6.1. These containers will be handled by the translift loader with units either staged on the siding or transloaded directly to and from the railcars and trucks. Translifts will be provided at the Weldon Spring site, the Wentzville siding, and the disposal site. General maintenance and assistance in loading and unloading at the siding will be provided by two laborers. In addition, 4 security guards will be required at the Wentzville siding on a 3-shift, 7-day-per-week basis.

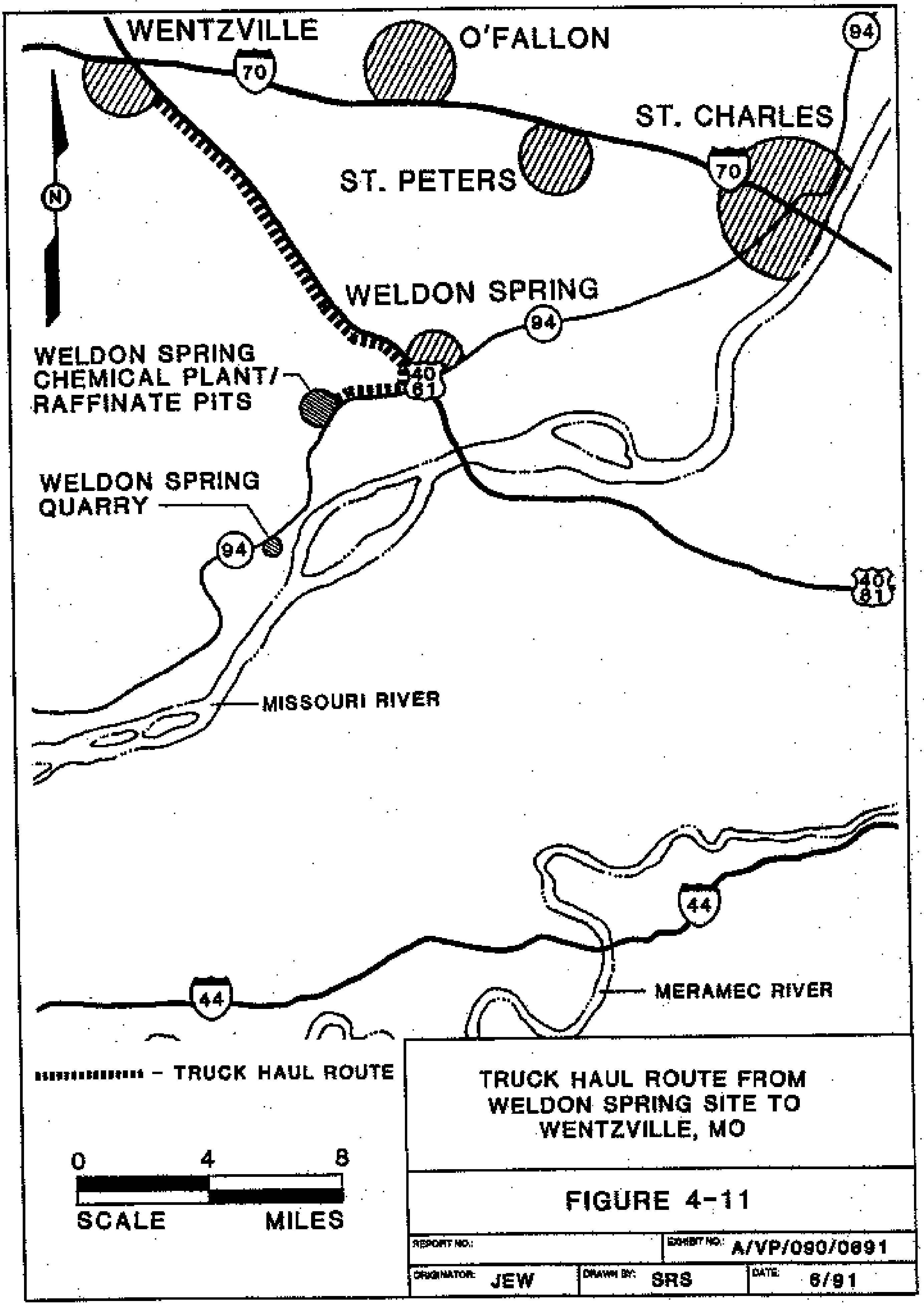
The Wentzville area currently has several sidings located in the vicinity; the Union Pacific Railroad will assist in locating a siding that could be used for staging and loading. The cost of leasing or purchasing an existing siding would be similar to the cost of constructing a new siding, but the cost of obtaining permits and the environmental impacts of construction would be avoided. For purposes of determining upper end costs for this study, it was assumed that new construction with associated permitting would be required.

4.4.6.5 Regulatory Requirements. The Weldon Spring wastes considered for off-site transportation include two types of radioactive material that must comply with U.S. Department of Transportation (DOT) regulations. These materials consist of building material contaminated with natural uranium and thorium,and their respective daughter products, and raffinate sludges which are contaminated with thorium-230. The requirements for the safe transportation of radioactive materials are cited in Title 49 Code of Federal Regulations. A more complete discussion of regulatory requirements is presented in Section 3 of the *Engineering Analysis of Remedial Action Alternatives, Phase I* (MKF and JEG 1992a).

Many states require advance notification and permitting for shipments of radioactive material entering their domain. This study does not address specific states or their respective notification requirements. This activity would be carried out if off-site transportation of Weldon Spring wastes was selected as the feasibility study preferred alternative.

4.4.6.6 Rail Routes. The most probable route to Clive, Utah, (alternative route Clive A), for off-site transport of Weldon Spring wastes on the Union Pacific Railroad would be through or near the following cities:

- **Missouri.** Pacific, Washington, Jefferson City, Sedalia, Kansas City.
- **Kansas.** Kansas City, Lawrence, Tecumseh, Topeka, Jeffrey, Marysville.
- **Nebraska.** Endicott, Hastings, Kearney, Cozad, North Platte, O'Fallons, Ogallala, Julesburg, Sidney.

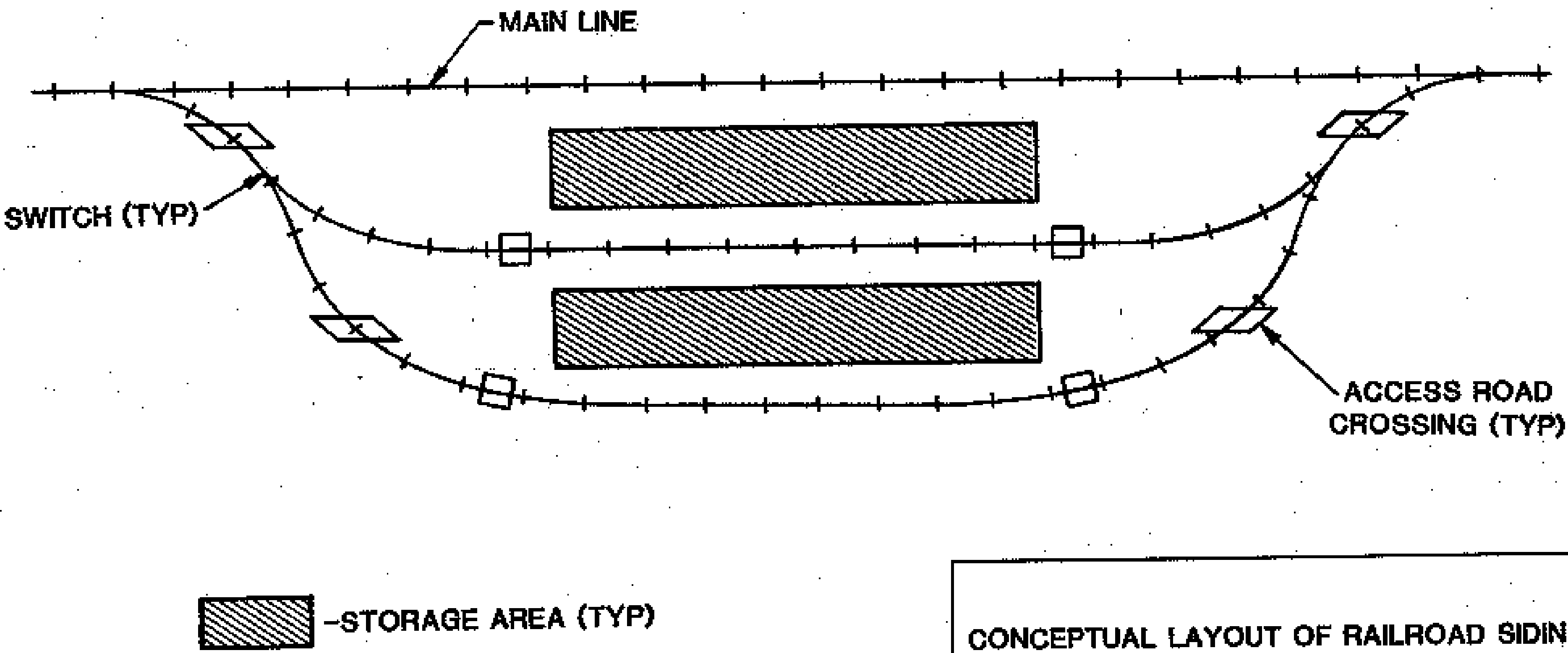


TRUCK HAUL ROUTE FROM WELDON SPRING SITE TO WENTZVILLE, MO

FIGURE 4-11

REPORT NO.:	EXHIBIT NO.: A/VP/090/0691

ORIGINATOR: JEW	DRAWN BY: SRS	DATE: 6/91

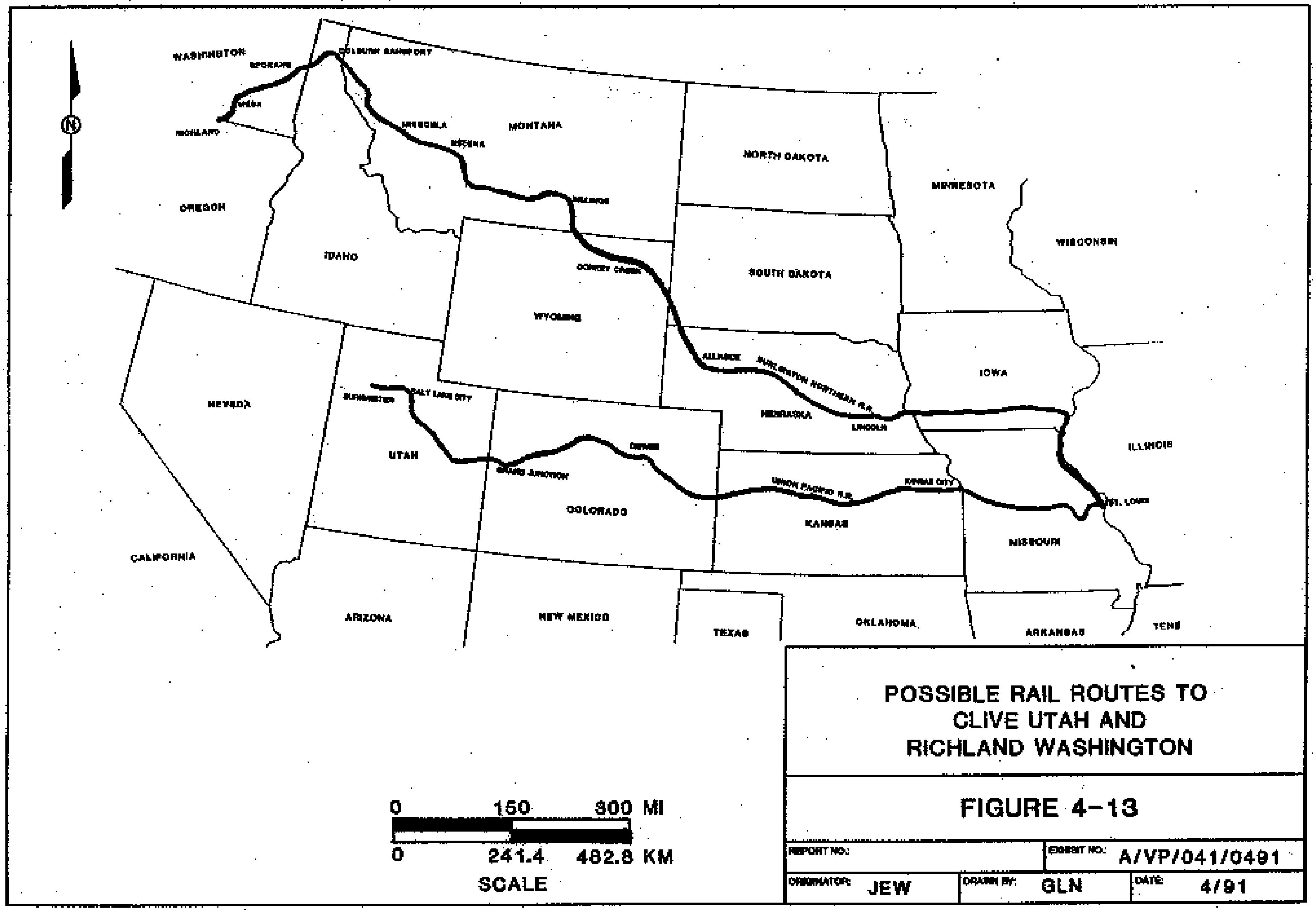


NOT TO SCALE

CONCEPTUAL LAYOUT OF RAILROAD SIDING

FIGURE 4-12

REPORT NO.:		EXHIBIT NO.:	A/PI/226/1191
ORIGINATOR: JEW	DRAWN BY: GLN	DATE:	1191



POSSIBLE RAIL ROUTES TO CLIVE UTAH AND RICHLAND WASHINGTON

FIGURE 4-13

REPORT NO:		EXHIBIT NO:	A/VP/041/0491
ORIGINATOR: JEW	DRAWN BY: GLN	DATE: 4/91	

- **Wyoming**. Speer, Cheyenne, Laramie, Rawlins, Wamsutter, Rock Springs, Green River, Alchem, Stauffer, Granger, Bridger, Evanston.

- **Utah**. Ogden, Clearfield, Salt Lake City, Garfield, Burmester, and Delle.

Alternative route Clive B starting at Topeka, Kansas, would pass through:

- **Kansas**. Abilene, Salina, Russell, Hays, Ellis, Wakeeney, Oakley, Sharon Springs.

- **Colorado**. Cheyenne Wells, Aroya, Hugo, Limon, Agate, Bennett, Denver, Granby, Orestod, Dotsero, Glenwood Springs, New Castle, Grand Junction, Fruita, Mack.

- **Utah**. Green River, Mounds, Price, Colton, Thistle, Springville, Provo, Midvale, Salt Lake City, Garfield, Burmester, and Delle.

These are the most direct routes from Weldon Spring to the Clive, Utah, site; numerous other routes are possible. The rail haul distance to Clive, Utah, is estimated to be 1,350 miles. The highway distance estimate, based on the Rand McNally Road Atlas, is 1,457 miles. The rail haul distance has been rounded up to 1,600 miles to account for variations in actual haul distance. Rail transportation cost is estimated to be $54/ton. Approximately 520 trips will be required, resulting in 832,000 transport miles traveled to Clive, Utah.

4.4.6.7 Spill Prevention and Spill Control. The Union Pacific Railroad employs emergency response teams throughout its rail system. Prior to shipment, information pertinent to the treated waste materials, such as specific properties of the waste and emergency handling data, will be logged into the railroad computer system. The emergency response teams will have access to that information and can react accordingly. The trains transporting Weldon Spring waste can also be tracked by satellite so that the trains' locations are known at all times.

Weldon Spring waste will include soil, vitrified material, and rubble; no liquids will be shipped to Clive for disposal. If an accident occurs and material is spilled, the emergency response team will load the materials into containers provided from the Wentzville staging area or from the disposal site. The spill area will subsequently be tested for residual contamination.

4.4.6.8 Acceptance Criteria. The disposal facility at Clive is operated by Envirocare of Utah under Radioactive Material License, No. UT2300249, initially issued on February 2, 1988 by the Utah Bureau of Radiation Control. Utah is an agreement state with the Nuclear

Regulatory Commission (NRC) for certain types of radioactive material. The license expires on February 28, 1993 and is subject to renewal.

The current amended license permits Envirocare to accept Naturally Occurring Radioactive Material (NORM) waste such as radium-225, source material, special nuclear material, 11(e)2 by-product material in limited quantities, and depleted uranium. Amendment Number 9 to the license, dated December 3, 1990, allows disposal of naturally occurring radioactive waste that contains hazardous constituents as permitted by the RCRA hazardous waste operations permit issued to Envirocare by the Executive Secretary of the Utah Bureau of Solid and Hazardous Waste and the Hazardous and Solid Waste Amendments of 1984 (HSWA) permit issued by the U.S. Environmental Protection Agency. The Amendment Number 9 waste must be placed in the mixed-waste disposal facility.

An environmental impact statement (EIS) is being prepared to assess impacts associated with facility acceptance of 11(e)2 by-product waste. The EIS is scheduled to be finalized in 1993.

4.4.6.9 Disposal Fees. Envirocare of Utah provided pricing information for this study based on limited data. The preliminary cost per ton information provided by Envirocare was $123 for 1,000,000 cubic yards of soil delivered over three years. The assumptions used by Envirocare differ from the assumptions used in this study. Consequently, final disposal costs may range from $123/ton to $165/ton. The increase in costs would result as the quantity of materials was reduced from the quoted delivery rate (1,000,000 yd^3) as an adjustment for economy of scale. Based on the 57% reduction expected for Weldon Spring wastes, a cost of $144/ton was used for this study. Envirocare will have to perform a detailed cost analysis before a firm price can be developed. The cost of unloading and dumping at the disposal cell will be included in the disposal fee.

4.4.7 Facilities Closure

Closure will be accomplished as described in Section 4.3.7 with the following exception. Foundations not processed at the volume reduction facility, such as those for the TSA, the MSA, the volume reduction facility, the water treatment plant, and the transfer station, will be demolished and loaded directly into containers for off-site transport.

4.4.8 Site Regrading

This task will be accomplished as described in Section 4.2.8.

4.5 Alternative 7C - Removal, Vitrification, and Off-Site Disposal at Richland, Washington

4.5.1 Site Preparation

Site preparation will be performed as described in Section 4.2.1.

4.5.2 Removal and On-Site Hauling of Waste Materials

Excavation and on-site transport of the Weldon Spring wastes will be accomplished for this alternative as described for Alternative 7B in Section 4.4.2.

4.5.3 Volume Reduction

Under this alternative, the size reduction methods and procedures will be the same as described in Section 4.4.3 for Alternative 7B.

4.5.4 Metals Decontamination

This activity may be performed as described in Section 4.2.4 for Alternative 6A.

4.5.5 Vitrification

The raffinate pit sludge, raffinate pit clay bottom material, quarry soils, and water treatment plant residues will be vitrified in a fossil fuel-heated ceramic melter as described in Section 4.3.5 for Alternative 7A.

4.5.6 Off-Site Disposal at Richland, Washington

Off-site transportation of Weldon Spring waste materials for disposal in the DOE's Hanford facility near Richland, Washington, will be the same as described in Section 4.4.6 with the following exceptions.

4.5.6.1 Railroad Transportation. The Burlington Northern Railroad serves both the St. Louis (Figure 4-13) and the Richland, Washington, areas and owns flatcars that accept the proposed intermodal containers. A Burlington Northern intermodal hub center is located at Pasco, Washington. However, using that facility would require trucking the containers from Pasco to the Hanford site and was, therefore, not considered.

The most probable route to Hanford, Washington (alternative route Hanford A) for off-site transport of Weldon Spring wastes on the Burlington Northern line would be through or near the cities listed below. Alternative route Hanford A would be the same as described for alternative route Clive A (Section 4.4.6.6) up to Granger, Wyoming. Beyond this point, alternative route Hanford A would pass through:

- **Wyoming.** Kemmerer.

- **Idaho.** Montpelier, Soda Springs, Epco, McCammon, American Falls, Minidoka, Shoshone, Gooding, Mountain Home, Orchard, Nampa, Caldwell, Nyssa, Payette, Weiser.

- **Oregon.** Huntington, Baker, LaGrande, Pendleton, Helix.

- **Washington.** Zangar Junction, Wallula, Attalia, Mesa, Kennewick, and Richland.

Alternative route Hanford B would pass through:

- **Missouri.** West Alton, Machens, Clarksville, Costrove, Hannibal, South River, Mark, Macon, Brookfield, Needles, Sumner, Birmingham, Kansas City, Sadler, Armour, St. Joseph, Forest City, Napier.

- **Nebraska.** Craig, Falls City, Table Rock, Lincoln, Weward, York, Aurora, Murphy Grand Island, Ravenna, Litchfield, Broken Bow, Thedford, Hyannis, Alliance, Hemingford, Crawford.

- **South Dakota.** Edgemont.

- **Wyoming.** Newcastle, Upton, Colloid Spur, Moorcroft, Donkey Creek, Campbell, Gillette, Dutch, Sheridan, Kleenburn.

- **Montana.** Hardin, East Billings, Billings, Laurel, Columbus, Livingston, Bozman, Belgrade, Logan, Trident, Toston, Townsend, Helena, Garrison, Phosphate, Drummond, Bonner, Missoula, De Smet, Schilling, Cedars, St. Regis, Paradise, Brownman, Thompson Falls.

- **Idaho.** Sandpoint, Hauser.

- **Washington.** Trentwood, Irvin, Marshall, Spokane, Cheney, Sprasgue, Toko, Ritzville, Lind, Connell, Mesa, Kennewick, Richland.

The haul distance from the Weldon Spring site to the Hanford facility is approximately 2,200 miles. Approximately 520 trips will be required, resulting in 1,144,000 miles traveled to the Hanford Reservation in Washington. Rail transportation cost is estimated to be $69/ton.

4.5.6.2 Acceptance Criteria. The acceptance criteria for Hanford are identified in the Hanford Site Radioactive Solid Waste Acceptance Criteria prepared by Westinghouse Hanford Company in 1990. The following materials are prohibited:

- Liquids.

- Reactive metals.

- Chemically incompatible materials in any waste container.

- Explosives.

- Pyrophorics.

- Chelating compounds.

- Gas cylinders that are not permanently vented.

- Unidentified, uncharacterized, or poorly characterized waste.

- No low-level radioactive waste exceeding Class C limits will be accepted by Westinghouse Hanford from licensees of the U.S. Nuclear Regulatory Commission

(NRC) or Agreement States except upon specific written approval by the DOE-RL with concurrence of DOE Headquarters.

Hanford is not presently prepared to receive the quantity of waste that will be generated at the Weldon Spring site. Special administrative and regulatory requirements would need to be addressed before they could do so.

4.5.6.3 Disposal Fees. Fees for disposal at Hanford are $100/cubic yard. This figure does not include closure or long-term monitoring costs and is very preliminary in nature. Earlier estimates had ranged as high as $1,944/cubic yard. Hanford presently receives only small quantities of waste material, and no administrative procedures are in place for disposing of Weldon Spring site wastes.

4.5.7 Facilities Closure

Site facilities will be demobilized as described above for Alternative 7B in Section 4.4.7.

4.5.8 Site Regrading

Upon completion of the work, the site will be regraded as described in Section 4.2.8 for Alternative 6A.

5 REDUCTION IN TOXICITY, MOBILITY, AND VOLUME

This section discusses the reduction of the toxicity, mobility, and volume of the Weldon Spring waste materials for each alternative considered in the feasibility study. Specifically addressed are the treatment processes and the materials to be treated; the amount of hazardous materials destroyed; the anticipated reduction in contaminant toxicity, mobility, and volume; the irreversibility of the treatment; and whether each alternative would satisfy the statutory preference for treatment as a principal element.

5.1 Material Quantities To Be Treated

The following discussion addresses the quantities of various waste materials identified for treatment. The discussion focuses on the material to be either vitrified or chemically treated. The remaining minimally contaminated material will not be treated, as discussed in Section 4. The total quantities of contaminated materials and the contaminant concentrations are reported in Section 1.3. The materials and quantities which are slated for either vitrification or chemical solidification/stabilization (CSS) treatment are shown in Table 4-9.

5.2 Reduction in Toxicity, Mobility, and Volume

The predicted change in contaminant toxicity, mobility, and volume resulting from treatment and disposal is discussed below for each alternative. This discussion focuses on the predicted changes resulting from 1) no further action, 2) chemical solidification/stabilization, and 3) fossil fuel-heated ceramic melting. Disposal of minimally contaminated material into either an on-site or off-site disposal facility will result in a common degree of contaminant isolation for the two treatment alternatives being considered.

5.2.1 Alternative 1 - No Further Action

None of the materials listed in Table 4-9 will be treated or destroyed and volumes will not be reduced under the no further action alternative. The only reduction in contaminant toxicity will be the result of the natural degradation of nitroaromatic compounds and the leaching of contaminants by precipitation. The leachate and runoff from the TSA, MSA, and the Ash Pond (if required) will be treated at the site water treatment plant and discharged to the Missouri River.

The contaminants in the building debris stored in the MSA and the quarry materials stored on the TSA will be essentially immobilized for at least the 10-year design life of the two storage facilities.

5.2.2 Alternative 6A - Removal, Chemical Stabilization, and On-site Disposal

The CSS process has been described in detail in Section 4.2.5. While CSS provides for a reduction in contaminant mobility, it does not result in the destruction of any contaminants. Although CSS will be used for treatment and on-site disposal for most site waste materials, liquid containerized chemicals and approximately 111 cubic yards of liquid waste and 30 tons of tributyl phosphate will be transported to Oak Ridge or a similar facility for incineration.

Recent tests performed by Waste Technology Group (WTG) in their Atlanta laboratory (WTG 1992) demonstrate that chemically stabilized raffinate pit sludge and quarry soils will pass the toxicity characteristics leaching procedure (TCLP). Previous Oak Ridge National Laboratory studies have demonstrated the ability of cement-stabilized waste to immobilize RCRA metals (Gilliam and Loflen 1985; Gilliam et al. 1986). The immobilization of polychlorinated biphenyls (PCBs) has been demonstrated after soil mixing using a cementitious proprietary additive and water (Stinson and Sawyer 1989). Chemically-solidified wastes containing PCBs, volatile organics, and metal contaminated soil have passed the TCLP test using proprietary additives, pozzolanic materials, and water (Grube 1989).

The cementitious reactions which occur during cement-mediated stabilization result in a significant loss of permeability and in some free water. The drainable free water from stabilized raffinate sludge quickly decreases with time. The drainage of free liquid ceased 21 days after treatment with the cement plus fly ash stabilizing agent (Gilliam and Francis 1989). This study utilized raffinate sludge samples containing approximately 80 weight percent moisture and 65 weight percent moisture contents. Dewatering techniques that would decrease the initial free water of the raffinate sludge or the mixing in of relatively drier soils and sediments may decrease the total quantity and duration of drainable free water after treatment.

Upon cessation of free water drainage, soluble contaminants can only be mobilized through leaching by infiltrating groundwater. Generally, the RCRA metals of concern show increased mobility in acidic solutions. Mobilization of selenium and arsenic are also strongly influenced by the redox potential (Eh) of a solution. Cement-stabilized products typically show a high capacity to buffer acidic solutions because of their alkaline constituents, CaOH and silica. Therefore, rapid dissolution of the stabilized mass by acidic solutions is unlikely.

Contaminant release from CSS media is a diffusion-controlled process. Contaminant flux is regulated by initial contaminant concentration, the contaminant diffusion coefficient, and the surface to volume ratio of the leaching solid. Formulae have been derived to estimate and simulate diffusion-controlled contaminant release. The following formula, based on Fick's 1st Law of Diffusion, was developed by Bishop (1988):

$$\frac{\Sigma an}{Ao} = 1.128\,(10^{-0.5\,Lx})(tn^{0.5})(s/v)$$

Where

Σan is amount leached during time n (mg)
Ao is initial amount (mg)
Lx is leachability index (-log of diffusion coefficient) (cm^2/s)
tn is time (s)
s is surface area (cm^2)
v is volume (cm^3)

Leachability indices range from about 7 (readily leachable) to 15 (immobile). Table 5-1 reports the time required for 100% removal ($\Sigma an/Ao=1$) of a contaminant from spheres of varying diameter.

TABLE 5-1 Time to Leach 100% of Contaminants Relative to Sphere Diameter and Leachability Index

Leachability Index	Diameter of Sphere .1-inch		1.0-inch		10-inches	
7	36	minutes	61	hours	253	days
8	384	minutes	606	hours	7	years
9	61	hours	253	days	69	years
10	606	hours	7	years	692	years
11	253	days	69	years	6,918	years
12	7	years	692	years	6,918	years
13	69	years	6,918	years	>6,918	years
14	692	years	>6,918	years	>6,918	years
15	6,918	years	>6,918	years	>6,918	years

Bishop (1988) reports leachability indices for cement-stabilized products ranging from 8 to 11 for cadmium, 9 to 11 for lead, and 10 to 11 for chromium, all much lower than the vitrified product. Rupp and Pankanian (1989) calculated a leachability index for lead and arsenic of >12.2 and >13.6, respectively. It is reasonable to predict that poorly attenuated compounds in CSS media (e.g., nitrate, nitroaromatics, uranyl ion) would likely have relatively lower leachability indices.

It should be noted that CSS product may have a maximum design life in aggressive leaching environments of about 500 years. During the final stages of CSS product degradation and dissolution, a decrease in the leachability index for a given contaminant is probable. Moreover, leachability of contaminants from CSS material is a function of exposed surface area. As the CSS product softens and fractures, an increase in the surface-to-volume ratio occurs with a consequent decrease in leachability index. However, the dissolution of spheres shown in Table 5-1 demonstrates that contaminants with relatively high Lx values (>11), contained in large fragments (>1-inch diameter) are reasonably well attenuated.

Throughout the Gilliam and Francis (1989) report, it was noted that chemically-stabilized product prepared with sludge from Raffinate Pit 4 consistently behaved differently from CSS products prepared with sludges from the other three pits. Products containing pit 4 sludge were characterized by more drainable water, larger volume increases, and spurious compressive strengths. Gilliam and Francis (1989) visually noted that the pit 4 raffinate sludge was less viscous, easier to stir, and had a higher sand-silt component than the sludge from the other raffinate pits. This observation, consistent with other researchers' data, suggests that differing chemical and physical compositions of waste impacts the setting characteristics of the chemically solidified/stabilized products. Unfortunately, Gilliam and Francis (1989) do not report comparative chemical analyses of the different raffinate sludges tested.

An MKES (*Stabilization Fatal Flaw Analysis* 1992b) study examining potential fatal flaws for CSS technology identified halides, various organics, sulfate, arsenate, and phosphate as potential set-inhibiting compounds. Degradation of CSS products containing set-inhibiting compounds should proceed more rapidly than products without set inhibitors present although the increased rate of deterioration has not been quantified. However, subsequent information suggests that halides and arsenate are below set-inhibiting concentrations within the Weldon Spring raffinate sludges. In addition, use of Type II Portland cement and ASTM Class F fly ash will prevent setting interferences that might occur due to the sulfate concentrations in the raffinate sludges.

Tributyl phosphate, chromium phosphate, and another unspecified phosphate were reportedly used during uranium concentrate processing at the Weldon Spring plant (DOE 1992b). Anomalously elevated phosphate concentrations in the Raffinate Pit 4 sludge could potentially have caused the differing grout behavior reported by Gilliam and Francis. However, Conner (1990) reports that sludge containing 7,000 ppm phosphate was successfully stabilized at another site. Therefore, it is likely that the Weldon Spring phosphate-bearing raffinate sludge can be successfully solidified.

A number of researchers have found, as reported in the CSS fatal flaw study (MKES 1992b), that relatively low levels (2%) of phenolic compounds decreased the final set strength of CSS products. Localized zones of the nitroaromatic-containing quarry soils may contain upwards of 2% total nitroaromatics. However, final set strength tests conducted by WTG on CSS product resulting from this material still exceeded the design criteria of an unconfined compressive strength of 50 psi (WTG 1992).

It is not currently possible to specifically predict the impact of variable chemical composition of the feed on contaminant leachability. Leachability studies reported in CSS literature emphasize a phenomenological approach rather than a mechanistic approach. As a result, it is difficult to directly extrapolate literature-reported leach rates developed under significantly different conditions, to the leachability of Weldon Spring CSS products. The results of future CSS bench-scale testing of Weldon Spring site-specific wastes should help define criteria to address leachability of contaminants.

Water-to-cement ratio is an important parameter in determining CSS product strength and porosity. Given sufficient water to fully hydrate cement (W/C:0.36), product strength decreases with increasing water to cement ratio. Moreover, free water will remain within the cement framework, creating porosity. A linear extrapolation of unconfined compressive strength versus water content of the material in the Gilliam and Francis study (1989) suggests failure of the 50-psi design criteria at a moisture content of 87%, using the recommended cement/fly ash blend. The CSS facility must, therefore, accommodate the feeding of raffinate sludge at a design moisture content of less than 87%, ideally at about 73% or less.

Alternative 6A specifies that the CSS product be disposed of in a disposal cell complete with a leachate collection and removal system and a cover with a radon barrier. Confinement of the CSS product in a disposal cell substantially decreases contaminant toxicity through contaminant immobilization and isolation. A disposal cell will significantly assist in the immobilization of contaminants and will help protect the CSS product from degradation due to exposure. The CSS product would remain in a largely undegraded state until the disposal cell had significantly failed to maintain its cover integrity. The proposed design life of the cell is 200 to 1,000 years. Failure of the disposal cell would allow infiltrating water to react with the cementitious material binding the contaminated media so that the treated product would begin to dissolve and weaken. During dissolution and weakening, contaminant leaching would increase because of increased contaminant diffusion through the solidified waste as a result of differential solution in fractures, degradation of the cement matrix, and an increased surface to volume ratio from fracturing and cracking.

5.2.3 Alternatives 7A, 7B and 7C - Removal, Vitrification, and On-site or Off-Site Disposal

As described for the CSS alternative, 220,000 cubic yards of raffinate sludge, 50,000 cubic yards of raffinate pit clay bottom, 50,000 cubic yards of quarry soils, 3,600 cubic yards of water treatment plant residues, and 28 cubic yards of drummed solid waste chemicals will be vitrified. At the operating temperatures considered for the vitrification of Weldon Spring wastes (1250°C to 1450°C), organic constituents will be destroyed. Conbsequently, the nitroaromatic organic compounds, contaminating approximately 7,000 tons of quarry soil, will be destroyed during vitrification.

Other compounds, such as nitrates, will also be destroyed during the vitrification process. The majority of the nitrates, however, will be removed from the raffinate sludge during physical dewatering. Nitrates and other soluble compounds will be contained in the wastewater stream pumped from the dewatering circuit to the wastewater treatment plant. Nitrates are very soluble compounds. Assuming that all of the nitrates in the raffinate sludge are soluble and that the dewatering process achieves raffinate sludge dewatering to 80% solids (an uncertainty until bench-scale testing is conducted), approximately 90% of the nitrates will be removed from the sludge prior to vitrification.

Nitrates (NO_3) that are not solubilized during dewatering will be converted by heat energy to gaseous molecules (N_2 and NO_x) during vitrification. The nitrogen not converted to molecular nitrogen, but instead converted to NO_x, can be destroyed during off-gas treatment by the addition of ammonia through the process represented by the following simplified equations:

$$4NH_3 + 4NO + O_2 \rightarrow 4N_2 + 6H_2O$$

$$4NH_3 + 2NO_2 + O_2 \rightarrow 3N_2 + 6H_2O$$

Nitrogen and oxygen produced from the destruction of nitrates will be released into the atmosphere.

Similar to nitrate, some sulfate will be volatilized during melting and removed in the off-gas treatment circuits. The amount of sulfate that will be retained in the melt produced during vitrification is not known nor is the mechanism well understood. As much as 3.5% sulfate has been retained in the vitrified product produced at the West Valley melter in New York (Ansted 1990). The actual fate of sulfate will be determined during the bench- and pilot-scale testing programs. The sulfate which is not retained in the melt will be converted to gaseous SO_x compounds which will be removed from the off-gas stream by acid-gas scrubbers. The waste from the off-gas treatment circuits will be recycled, to the extent practical, and bled off, as required. The sulfur compounds removed from the off-gas system from bleed-off at the secondary scrubber blowdown will require appropriate disposal or further treatment, such as chemical solidification/stabilization, prior to disposal.

The majority of the metals and radionuclides will be retained in the final glass product. Some of these elements (arsenic, cadmium, mercury, zinc, and selenium) may be volatilized to varying degrees during vitrification. The actual amounts of volatilized metals will be determined during bench-scale testing. Volatilized metals will be captured in the off-gas treatment circuits, recycled as practical, and bled off, as required. Those contaminants removed from the off-gas system from bleed-off at the secondary scrubber blowdown will also require appropriate disposal or further treatment, such as chemical solidification/stabilization, prior to disposal.

Table 5-2 lists the estimated amount of each contaminant, compound, or element initially present in the waste feed materials and its estimated fate after waste vitrification.

TABLE 5-2 Fate of Contaminants Resulting from Vitrification

		Fate of Contaminants As Percent of Feed		
Contaminant	Annual Feed Rate (tons)[a]	Encased in Glass Frit (%)	Scrubber Residuals for Disposal (%)	Released to the Atmosphere[b] (%)
Lead	17.3	93.12	6.88	1.8e-06
Arsenic	28.3	77.57	22.43	5.9e-06
Cadmium	1.4	75.05	24.95	6.6e-06
Selenium	2.3	0.06	99.94	2.6e-05

TABLE 5-2 Fate of Contaminants Resulting from Vitrification (Continued)

Mercury	0.3	0.00	40.00	60.00
Copper	18.7	99.77	0.23	1.2e-08
Nickel	21.4	99.77	0.23	1.2e-08
Chromium	2.4	99.77	0.23	1.2e-08
Vanadium	196.2	99.77	0.23	1.2e-08
Zinc	16.9	98.18	1.82	9.2e-08
Sulfate	262.3	74.07	23.33	2.59 (c)
Chloride	0.3	0.10	94.90	4.99 (d)
Fluoride	2.3	99.77	0.23	2.3e-03 (e)
Nitrites	1.4	0.00	50.00	50.00 (f)
Nitrates	141.0	0.00	50.00	50.00 (f)
Organic - NO_2	1.3	0.00	50.00	50.00 (f)
Thermal NOx	273.8	0.00	95.30	95.30 (g)
2,4,6 TNT	5.9	<0.10	<0.10	0.0001 (h)
2,4 DNT	0.2	<0.10	<0.10	0.0001 (h)
2,6 DNT	0.2	<0.10	<0.10	0.0001 (h)
Radionuclides (Ci)				
U-234	24.1	99.77	0.23	1.2e-08
U-238	27.9	99.77	0.23	1.2e-08
Th-230	468.0	99.77	0.23	1.2e-08
Th-232	5.3	99.77	0.23	1.2e-08
Ra-226	23.6	99.77	0.23	1.2e-08
Ra-228	6.7	99.77	0.23	1.2e-08
Pb-210	58.5	93.12	6.88	1.8e-08
Po-210	55.1	99.77	0.23	1.2e-08
Rn-222		0.09977	0.23	0.00016 (i)
Total Activity	658.0	99.18	0.82	1.7e-07
Total Non-Volatile Solids:	45,625.0	99.77	0.23	1.2e-08

Notes:

(a) Based on annualized daily average feed of 125 tons per day. This mass balance represents expected-case or base-case scrubber efficiencies.

(b) These are expected- or base-case emissions. Worst-case emissions are expected to be within acceptable limits, with the possible exception of NO_2 which is being modeled by ANL.

(c) Sulfate is released as SO_2.

(d) Chloride is released as HCl.

(e) Fluorides are not expected to volatilize;it is therefore assumed to be released in its original mineral form, probably apatite.

(f) Nitrates, nitrites, and organic nitro groups are released as NO_2.

(g) Thermal NOx is not present in the feed but is created from nitrogen and oxygen in the air. Thermal NOx quantities are reported as percentages of the NO_2-forming components of the feed (nitrates, nitrites, and organic nitro groups).

(h) Organic fates are based on the minimum destruction and removal efficiency of 99.9999% for PCBs, which are more difficult to pyrolize, for both in situ and plasma arc vitrification processes. Partitioning between glass and scrubber sludge is based on treatment system efficiencies of 99.9% and destruction efficiencies of 99.9% for PCBs during in situ vitrification.

(i) Radon percentages are based on the amount of radon that would otherwise be released over a 70-year period from material that has not been vitrified. This time period is the length of time typically used as a basis for risk assessment. For scrubber residuals, this is equal to the percentage of radium-226 in the scrubber sludge. For the glass, it is equal to the percentage of radium-226 in the glass times the 0.001 reduction in surface emanation reported by PNL for the Weldon Spring test glass. For the air emissions from the process itself, this is equal to the fraction of the 70-year period that the material resides in the melter (residence time = 1 hour). Radon emitted during excavation and handling is assumed to be the same for vitrification as for the CSS process. A 99.67% overall reduction occurs for the 70-year period.

Many factors which affect the destruction and removal efficiencies (DREs) for the contaminants are not presently known. The extent of partitioning of the contaminants not destroyed between the melt and the stages in the off-gas system is also unknown. These factors must be determined during bench- and pilot-scale testing using Weldon Spring wastes. These testing programs will determine the DREs for contaminants which are destroyed and the process parameters which are optimal for the greatest partitioning of the non-destroyed contaminants into the melt and, therefore, into the glass produced. Operating parameters, such as feed mixtures, melting temperatures, reaction chamber temperature, and residence time, and the amount of excess air required in the melter for destruction of particular contaminants will also be determined during the bench- and pilot-scale testing programs.

The proposed fossil fuel-heated ceramic melter does not require the use of melt-modifying reagents to process the contaminated media slated for treatment. Silica-rich raffinate pit clay bottom and/or quarry soil will be mixed with the dewatered raffinate sludge to produce a non-devitrifiable glass product. The volatilization of water results in a significant decrease in the tonnage of the glass product relative to the feed. This tonnage decrease is particularly evident during raffinate sludge processing. Physical and thermal dewatering of the raffinate sludge will result in a 73% tonnage reduction. The volume reduction is less significant due to the interstitial porosity between the grains of the fritted glass product. An estimated volume reduction of 68% over the feed material will be achieved.

As discussed previously, at the processing temperatures reached during vitrification, organics and nitrate will be destroyed. A DRE of 99.9999 is estimated to be achievable for these constituents. Sulfate may be destroyed or retained in the glass product. Tables 5-3 and 5-4 report the highest short-term controlled emission and average long-term controlled emission estimates based upon contaminant concentrations and expected filter control efficiencies, respectively.

Contaminant release from a vitrified product is a diffusion-controlled process. Contaminant flux is regulated by initial contaminant concentration, the contaminant diffusion coefficient, and the surface-to-volume ratio of the leaching solid. Formulae have been derived to estimate and simulate diffusion-controlled contaminant release. The following formula, based on Fick's 1st Law of Diffusion, was developed by Bishop (1988):

TABLE 5-3 Highest Short-term Controlled Emission Estimates

Nominal Waste Feed Rate: 200 tpd

Contaminants of Concern	Highest Short-term Concentration in waste	Feed Rate into Melter (lb/hr)	Minimum Expected Soil-to Off-gas Factor (DF)	Off-gas Mass Flow (lb/hr)	PRIMARY/QUENCH SCRUBBER (EJEC-VENT): Minimum Expected Contrl Efficiency (% EFF)	PRIMARY/QUENCH SCRUBBER (EJEC-VENT): Minimum Expected Contrl Efficiency (DF)	PRIMARY/QUENCH SCRUBBER (EJEC-VENT): Solids Recycle Mass Flow (lb/hr)	PRIMARY/QUENCH SCRUBBER (EJEC-VENT): Outlet Gas Mass Flow (lb/hr)	HIGH-EFFIC. AEROSOL/ACID-GAS SCRUBBER: Minimum Expected Contrl Efficiency (% EFF)	HIGH-EFFIC. AEROSOL/ACID-GAS SCRUBBER: Minimum Expected Contrl Efficiency (DF)	HIGH-EFFIC. AEROSOL/ACID-GAS SCRUBBER: Solids Mass Blowdown (lb/hr)	HIGH-EFFIC. AEROSOL/ACID-GAS SCRUBBER: Outlet Gas Mass Flow (lb/hr)	Final Filter Decontam Factor 1 HEPA (DF)	Controlled Emission Rate (lb/hr) or (pCi/d)
Solids(PM-10)	1.e+06µg/g	16666.67	33.3	500.50	90	10	450.45	50.05	98	50	49.05	1.001	2000	0.0005 lb/hr
METALS/METALLOIDS														
lead	1400 µg/g	23.33	10	2.33	20	1.25	0.47	1.87	40	1.67	0.75	1.120	2000	0.0006 lb/hr
arsenic	2000 µg/g	33.33	3.3	10.10	20	1.25	2.02	8.08	40	1.67	3.23	4.848	2000	0.0024 lb/hr
cadmium	644 µg/g	10.73	3	3.58	20	1.25	0.72	2.86	40	1.67	1.14	1.717	2000	0.0009 lb/hr
selenium	160 µg/g	2.67	1	2.67	20	1.25	0.53	2.13	40	1.67	0.85	1.280	2000	0.0006 lb/hr
mercury	32 µg/g	0.52	1	0.52	20	1.25	0.10	0.41	40	1.67	0.17	0.248	1	0.2480 lb/hr
ANIONS/ACID-GASES														
nitrites (a)	225 µg/g	3.75	1	3.75	7	1.08	0.26	3.49	25	1.33	0.87	2.616	1	2.62 lb/hr NO2
nitrates (a)	22100 µg/g	368.33	1	273.28	7	1.08	19.13	254.15	25	1.33	63.54	190.613	1	190.61 lb/hr NO2
sulfates	14500 µg/g	241.67	1	161.11	50	2	80.56	80.56	90	10	72.50	8.056	1	8.06 lb/hr SO2
chlorine (b)	40.5 µg/g	0.68	1	0.69	50	2	0.35	0.35	90	10	0.31	0.035	1	0.03 lb/hr HCL
fluorine	306 µg/g	5.10	1	5.37	50	2	2.68	2.68	90	10	2.42	0.268	1	0.27 lb/hr HF
NITRO-AROMATICS														
2,4,6 TNT	1600 µg/g	26.67	10000	0.00267	0	1	0.00000	0.00267	0	1	0.00000	0.00267	1	0.00267 lb/hr
2,4 DNT	33 µg/g	0.55	10000	0.00006	0	1	0.00000	0.00006	0	1	0.00000	0.00006	1	0.00006 lb/hr
2,6 DNT	68 µg/g	1.13	10000	0.00011	0	1	0.00000	0.00011	0	1	0.00000	0.00011	1	0.00011 lb/hr
RADIONUCLIDES		(pCi/d)		(pCi/d)			(pCi/d)	(pCi/d)			(pCi/d)	(pCi/d)		
U-234	2950 pCi/g	5.35e+11	10000	5.35e+07	90	10	4.8e+07	5.4e+06	98	50	5.2e+06	1.07e+05	2000	53.5 pCi/d
U-238	4200 pCi/g	7.62e+11	10000	7.62e+07	90	10	6.9e+07	7.6e+06	98	50	7.5e+06	1.52e+05	2000	76.2 pCi/d
Th-230	138400 pCi/g	2.51e+13	10000	2.51e+09	90	10	2.3e+09	2.5e+08	98	50	2.5e+08	5.02e+06	2000	2511.1 pCi/d
Th-232	1568 pCi/g	2.84e+11	10000	2.84e+07	90	10	2.6e+07	2.8e+06	98	50	2.8e+06	5.69e+04	2000	28.4 pCi/d
Ra-226	3200 pCi/g	5.81e+11	1000	5.81e+08	90	10	5.2e+08	5.8e+07	98	50	5.7e+07	1.16e+06	2000	580.6 pCi/d
Ra-228	2200 pCi/g	3.99e+11	1000	3.99e+08	90	10	3.6e+08	4.0e+07	98	50	3.9e+07	7.98e+05	2000	399.2 pCi/d
Pb-210	5400 pCi/g	9.80e+11	10	9.80e+10	20	1.25	2.0e+10	7.8e+10	40	1.67	3.1e+10	4.70e+10	2000	2.4e+07 pCi/d
Po-210	5400 pCi/g	9.80e+11	1000	9.80e+08	90	10	8.8e+08	9.8e+07	98	50	9.6e+07	1.96e+06	2000	979.8 pCi/d
TOTAL RAD	1.6e+05pCi/g	3.0e+13		1.0e+11			2.4e+10	7.9e+10			3.2e+10	4.7e+10		2.4e+07 pCi/d

NOTES: (a) Organic nitro groups ($-NO_2$) will add 3 lb/hr before control to the NOx emissions reported above for nitrates and nitrites for a total feed NOx emission rate (before control) of 280 lb/hr. In addition, combustion NOx will add 180 lb/hr short-term maximum conditions. Thus total NOx from all sources is 460 lb/hr before control, 320 lb/hr after.

(b) Organic chlorine will add 0.11 lb/hr HCl before control or .0055 lb/hr after control to the HCl of inorganic origin reported above.

TABLE 5-4 Average Long-term Controlled Emission Estimates

Nominal Feed Rate: 125 tpd

Contaminants of Concern	Long-Term Average Concentration in waste	Feed Rate into Melter (lb/hr)	Minimum Expected Soil-to Off-gas Factor (DF)	Off-gas Mass Flow (lb/hr)	PRIMARY/QUENCH SCRUBBER (EJEC-VENT) Minimum Expected Contrl Efficiency (% EFF)	(DF)	Solids Recycle Mass Flow (lb/hr)	Outlet Gas Mass Flow (lb/hr)	HIGH-EFFIC. AEROSOL/ACID-GAS SCRUBBER Minimum Expected Contrl Efficiency (% EFF)	(DF)	Solids Mass Blowdown (lb/hr)	Outlet Gas Mass Flow (lb/hr)	Final Filter Decontam Factor 1 HEPA (DF)	Controlled Emission Rate (lb/hr) or (pCi/d)
Solids (PM-10)	1.e+06µg/g	10416.67	33.3	312.81	90	10	281.53	31.28	98	50	30.66	0.626	2000	0.00031 lb/hr
METALS/METALLOIDS														
lead	380 µg/g	3.96	10	0.40	20	1.25	0.08	0.32	40	1.67	0.13	0.190	2000	0.00010 lb/hr
arsenic	620 µg/g	6.46	3.3	1.96	20	1.25	0.39	1.57	40	1.67	0.63	0.94	2000	0.00047 lb/hr
cadmium	30 µg/g	0.31	3	0.10	20	1.25	0.02	0.08	40	1.67	0.03	0.050	2000	0.00003 lb/hr
selenium	50 µg/g	0.52	1	0.52	20	1.25	0.10	0.42	40	1.67	0.17	0.250	2000	0.00013 lb/hr
mercury	6 µg/g	0.06	1	0.06	20	1.25	0.01	0.05	40	1.67	0.02	0.030	1	0.03000 lb/hr
ANIONS/ACID-GASES														
nitrites (a)	31.6 µg/g	0.33	1	0.33	7	1.08	0.02	0.31	25	1.33	0.077	0.233	1	0.233 lb/hr NO2
nitrates (a)	3090 µg/g	32.19	1	23.88	7	1.08	1.67	22.21	25	1.33	5.5	16.7	1	16.7 lb/hr NO2
sulfates	5750 µg/g	59.90	1	39.93	50	2	19.97	19.97	90	10	17.97	1.997	1	1.9965 lb/hr SO2
chlorine (b)	6.6 µg/g	0.07	1	0.07	50	2	0.04	0.04	90	10	0.03	0.004	1	0.0035 lb/hr HCL
fluorine	50.5 µg/g	0.53	1	0.55	50	2	0.28	0.28	90	10	0.25	0.028	1	0.0277 lb/hr HF
NITRO-AROMATICS														
2,4,6 TNT	130 µg/g	1.35	10000	0.000135	0	1	0.000000	0.000135	0	1	0.000000	0.000135	1	0.000135 lb/hr
2,4 DNT	4.1 µg/g	0.04	10000	0.000004	0	1	0.000000	0.000004	0	1	0.000000	0.000004	1	0.000004 lb/hr
2,6 DNT	4.8 µg/g	0.05	10000	0.000005	0	1	0.000000	0.000005	0	1	0.000000	0.000005	1	0.000005 lb/hr
RADIONUCLIDES		(pCi/d)		(pCi/d)			(pCi/d)	(pCi/d)			(pCi/d)	(pCi/d)		
U-234	582 pCi/g	6.06	10000	6.1e-04	90	10	5.5e-04	6.1e-05	98	50	5.9e-05	1.2e-06	2000	6.1e-10 pCi/d
U-238	673 pCi/g	7.01	10000	7.0e-04	90	10	6.3e-04	7.0e-05	98	50	6.9e-05	1.4e-06	2000	7.0e-10 pCi/d
Th-230	11060 pCi/g	115.21	10000	1.2e-02	90	10	1.0e-02	1.2e-03	98	50	1.1e-03	2.3e-05	2000	1.2e-08 pCi/d
Th-232	129 pCi/g	1.34	10000	1.3e-04	90	10	1.2e-04	1.3e-05	98	50	1.3e-05	2.7e-07	2000	1.3e-10 pCi/d
Ra-226	571 pCi/g	5.95	1000	5.9e-03	90	10	5.4e-03	5.9e-04	98	50	5.8e-04	1.2e-05	2000	5.9e-09 pCi/d
Ra-228	138 pCi/g	1.44	1000	1.4e-03	90	10	1.3e-03	1.4e-04	98	50	1.4e-04	2.9e-06	2000	1.4e-09 pCi/d
Pb-210	1413 pCi/g	14.72	10	1.5e+00	20	1.25	2.9e-01	1.2e+00	40	1.67	4.7e-01	7.1e-01	2000	3.5e-04 pCi/d
Po-210	1331 pCi/g	13.86	1000	1.4e-02	90	10	1.2e-02	1.4e-03	98	50	1.4e-03	2.8e-05	2000	1.4e-08 pCi/d
TOTAL RAD	15897 pCi/g	165.59		1.5e+00			3.3e-01	1.2e+00			4.7e-01	7.1e-01		3.5e-04 pCi/d

NOTES: (a) Organic nitro- groups ($-NO_2$) will add an additional 1% NOx for a total feed NO_2 emission rate of 24.5 lb/hr before control and 17 lb/hr after control.
(b) Organic chlorine will add 25% additional HCl, resulting in a total HCl emission rate of .088 lb/hr before control and .0044 lb/hr after control.

$$\frac{\Sigma an}{Ao} = 1.128\,(10^{-0.5\,Lx})(tn^{0.5})(s/v)$$

Where

Σan	is amount leached during time n (mg)
Ao	is initial amount (mg)
Lx	is leachability index (-log of diffusion coefficient) (cm^2/s)
tn	is time (s)
s	is surface area (cm^2)
v	is volume (cm^3)

Leachability indices range from about 7 (readily leachable) to 15 (immobile). Table 5-5 reports the time required for 100% removal ($\Sigma an/Ao = 1$) of a contaminant from a 0.1-inch-diameter sphere.

TABLE 5-5 Time to Leach 100% of Contaminants Relative to Leachability Index

Leachability Index	Sphere Diameter of .1-inch: Time to Leach
7	36 minutes
8	364 minutes
9	61 hours
10	606 hours
11	253 days
12	7 years
13	69 years
14	692 years
15	6,918 years

Diffusion coefficient, or leachability index, data are unavailable for vitrified product. However, TCLP data and geologic evidence suggest that very high Lx values are likely (>14). Natural volcanic glass (obsidian), age-dated at several million years, typically contains uniform trace element concentrations throughout the unit; diffusion-controlled leached rinds are either absent or are only a few millimeters thick. Zoned plagioclase feldspar crystals, having differing sodium and calcium contents within the mineral lattice, remain in specimens age-dated to tens of millions of years. Consequently, solid-state diffusion processes must be very slow to allow the sodium/calcium zonation to be preserved in these geological samples.

Kinetic calculations demonstrate that 0.1-inch-diameter glass beads require tens of millions of years for dissolution, even under relatively aggressive natural conditions. Therefore, analysis of the leachability data in the above table suggests that contaminants in 0.1-inch-diameter glass spheres are retained for hundreds to thousands of years. Importantly, it is unlikely that any decrease of the Lx values will be observed over the first few thousand years of vitrified product life.

Silica is the most important chemical in controlling contaminant leachability. Vitrification of material with silica content exceeding 50% by weight will result in a highly unleachable glass. The lack of sufficient silica in the raffinate sludges necessitates the addition of silica-rich soil to the raffinate sludge prior to vitrification in order to produce a non-devitrifiable and nonleachable glass.

The slow estimated contaminant release rates are substantiated by leachability testing. Koegler et al. (1989) demonstrated the effectiveness of vitrification in treating Weldon Spring raffinate sludge and soil in a bench-scale test. Samples of the vitrified block were leach-tested using EP Toxicity procedures and 7-day and 28-day MCC-1 and MCC-3 leach test procedures. Although the tested glasses were produced by different thermal technologies, the results are comparable to glass produced by fossil fuel-heated ceramic melting. The results of these tests are presented below in Tables 5-6, 5-7, and 5-8.

TABLE 5-6 EP Toxicity Concentrations for Vitrified Glass

	EP Toxicity Conc. for WS Glass (mg/l)	Max. Allowable Tox. Conc. (mg/l)
Arsenic	<1.0	5.0
Barium	0.04	100.0
Cadmium	0.01	1.0
Lead	<1.0	5.0
Chromium	<1.0	5.0
Mercury	<0.03	0.2
Selenium	<0.01	1.0
Silver	<0.1	5.0

TABLE 5-7 Vitrified Glass 7-Day Average Leach Test Results for Weldon Spring Samples

	Normalized Elemental Release (g/m^2)	
	MCC-1	MCC-3
Aluminum	0.90	0.01
Boron	0.00	0.09
Calcium	1.50	0.28
Iron	1.29	0.00
Potassium	0.00	0.06
Sodium	1.20	0.09
Silicon	0.80	0.04
Vanadium	0.00	0.25
Final pH	5.08	9.77

TABLE 5-8 Vitrified Glass 28-Day Average Leach Test Results for Weldon Spring Samples

	Normalized Elemental Release (g/m^2)	
	MCC-1	MCC-3
Aluminum	2.77	0.01
Boron	2.77	0.12
Calcium	8.73	0.33
Iron	0.56	0.00
Potassium	3.67	0.09
Sodium	3.15	0.11
Silicon	2.95	0.06
Vanadium	0.00	0.45
Final pH	8.75	9.79

Laboratory-scale crucible tests of the joule-heated ceramic melter (JHCM) process were also performed on samples of Weldon Spring raffinate sludge, raffinate pit clay bottom, and vicinity soils (Koegler et al. 1989). Results of the leach tests on the vitrified product are presented below in Tables 5-9, 5-10, and 5-11. These results are very likely comparable to the results from glass produced by a fossil fuel-heated ceramic melter.

TABLE 5-9 EP Toxicity Concentrations for the JHCM Glass

	EP Toxicity Conc. for WS Glass (mg/l)	Max. Allowable Tox. Conc. (mg/l)
Arsenic	<1.0	5.0
Barium	0.04	100.0
Cadmium	<0.01	1.0
Lead	<1.0	5.0
Chromium	<1.0	5.0
Mercury	<0.03	0.2
Selenium	<0.01	1.0
Silver	<0.1	5.0

TABLE 5-10 JHCM Glass 7-Day Average Leach Test Results for Weldon Spring Samples

Normalized Elemental Release (g/m^2)

	MCC-1	MCC-3
Aluminum	7.24	0.19
Boron	11.32	0.26
Calcium	8.19	0.01
Iron	0.48	0.01
Potassium	8.50	0.28
Molybdenum	10.12	0.85
Sodium	11.33	0.89
Phosphorous	6.51	0.10
Silicon	8.47	0.24
Vanadium	12.52	0.29
Final pH	10.03	11.71

TABLE 5-11 JHCM Glass 28-Day Average Leach Test Results for Weldon Spring Samples

Normalized Elemental Release (g/m^2)

	MCC-1	MCC-3
Aluminum	8.49	0.29
Boron	13.78	0.30
Calcium	9.70	0.01
Iron	0.66	0.01

Potassium	13.11	0.39
Molybdenum	14.15	0.82
Sodium	14.12	1.36
Phosphorous	10.54	0.16
Silicon	10.17	0.37
Vanadium	15.58	0.32
Final pH	9.94	11.96

The above data provided by Koegler et al. (1989) describes the EP Toxicity test as having been conducted in deionized water. According to EPA, this test should be conducted in deionized water which is adjusted to a pH of 5.0 with 0.5N acetic acid. The report did not clearly state if the test had been conducted under the actual conditions specified in the EPA protocol. Whether or not this protocol was followed, it is now required that a waste suspected of being characteristically toxic be tested using the TCLP protocol rather than the EP Toxicity protocol. TCLP testing will be performed in conjunction with further bench-scale or pilot-scale vitrification testing. Ongoing literature review has yet to identify a vitrified product failing TCLP or similar leaching criteria.

The variable chemical composition of the vitrification plant feed material has led to concerns regarding glass product quality. Consequently, the chemical characteristics of the Weldon Spring wastes were evaluated (MKES 1992c), and no operational fatal flaws were found for fossil fuel-heated ceramic melting. The potential does exist for immiscible phase development in the FFHCM-produced melt. The immiscible phases which may occur could be iron, sulfide, or sulfate-rich phases, depending on the relative oxidation and sulfur content of the melt.

A reducing melt condition would favor the formation of an iron- and/or sulfide-immiscible phase. An iron phase could concentrate cadmium, lead, silver, and copper, depending upon the emperature of the melt. It is unlikely that an iron phase so enriched would cause the resulting solid to fail the TCLP test for those contaminants. It is important to note that the short residence time in the melter will minimize the potential for immiscible phase development. The absence of native iron and organic carbon, as a quantitatively significant portion of the feed will also help prevent development of an immiscible iron phase.

A sulfur-rich phase formed in a reducing environment would manifest itself as a sulfide phase. Again, certain elements, such as copper, silver, zinc, cadmium, mercury, lead, selenium, and arsenic, would tend to partition into this phase. Efficient partitioning of these contaminants into the sulfide phase during vitrification would yield a sulfide-dominated product containing anomalously concentrated contaminants. Exposure of this product to oxygenated water could result in the oxidation of the sulfide mass which would generate an acidic, contaminant-rich solution. It is possible that the kinetically slow release of contaminants from a silica-encapsulated sulfide mass may allow passage of the TCLP criteria.

A sulfur-rich phase formed in an oxidizing melter environment would manifest itself as a sulfate phase. A sulfate phase would probably be enriched in magnesium, calcium, strontium, barium, radium, uranium (UO_2^{2+}), lead, and cadmium. The actual concentration of these elements in a sulfate phase may have to be determined by measuring the distribution coefficients of these elements. If this phase were in contact with water, it could dissolve and release contaminants concentrated in the sulfate phase, probably as gypsum or anhydrite. Conceivably, a cooled sulfate phase could fail the TCLP test for concentrated metals, if not sufficiently encapsulated by silica. If an immiscible sulfate phase were generated during vitrification of the Weldon Spring wastes and was found to unfavorably affect the leaching characteristics of the glass produced, this phase could be controlled or eliminated by adjusting the cooling rate of the product or by optimizing the redox potential of the melt.

It is important to note that a sulfate phase would be a volumetrically minor component of the glass. Assuming that none of the sulfate were volatilized or solubilized into the melt and based on data from the site Remedial Investigation report (DOE 1992b), it is possible that the average glass could have approximately 0.775% (volume) to a maximum of 1.83% (volume) sulfate as $CaSO_4$ (anhydrite). Data from Koegler et al. (1989) indicate a much higher SO_4 content in the raffinate sludge, which would correlate to 5.97% (volume) $CaSO_4$ in the glass produced.

The sulfate phase would be dispersed throughout the melt unless enough time were allowed for this phase to become separated from the silica phase and to coalesce. A volumetrically important quantity of non-silica-encapsulated sulfate phase could only be produced by quantitatively removing the silica phase from the sulfate phase. The short residence times required in existing melting systems will not allow this phase separation to occur. If a sulfate phase does not separate from the melt and coalesce, the sulfate phase will be trapped within the silica phase. Rapid cooling of this melt would cause the sulfate phase to remain encapsulated within the glass, minimizing its ability to leach. Rapid cooling of the glass would be accomplished by quenching the melt in water and producing a fritted product. Other rapid cooling methods are available, such as dropping the glass onto a spinning steel platform which cools the glass and forms marble-like glass lozenges. Either of these production methods should generate a glass capable of passing the TCLP criteria. It is important to restate that a literature review did not reveal any data documenting a glass product ever failing the TCLP or other leach test criteria.

Contaminant toxicity will be significantly decreased by vitrification and isolation in an engineered disposal cell. Organics and nitrate will be destroyed during treatment. Sulfate will be destroyed or retained in the glass. Certain volatile contaminants will be contained by the off-gas treatment system. The contaminants retained in the glass will be immobilized for thousands of years, only very slowly diffusing from the glass. The vitrified product will be disposed of into an on-site UMTRA-type cell or into an off-site disposal cell meeting regulatory standards. Either cell type will help attenuate radon emissions from the radioactively contaminated glass product and will isolate the product from groundwater and the environment.

5.3 Irreversibility of Treatment

The following discussion addresses the degree to which treatment will be irreversible for each alternative.

5.3.1 Alternative 1 - No Further Action

Temporary storage of soil, building debris, and other materials at the MSA and TSA is reversible. The material will be readily available for additional remediation at any time.

5.3.2 Alternative 6A - Removal, Chemical Stabilization, and On-Site Disposal

Chemical solidification/stabilization does not produce any irreversible effects. Contaminants are not destroyed, only immobilized. The immobilization process is also not irreversible to the same degree as achieved by vitrification. Contaminants are typically attenuated due to adsorption onto ferric hydroxide precipitates, precipitated as relatively insoluble hydroxide compounds, and/or encapsulated into the cementitious mineral framework. Cement/fly ash mixtures are known to degrade, typically within tens to a few hundred years. Upon exposure to infiltrating water, contaminants may be leached from the CSS product. The CSS product is not in an irreversible state in that it could potentially be vitrified or hydrometallurgically processed. However, CSS product placed in a disposal cell, while not totally irreversible, would be quite difficult to remove after setting has occurred.

5.3.3 Alternatives 7A, 7B and 7C - Removal, Vitrification, and On-Site or Off-Site Disposal

Vitrification results in the irreversible destruction of organic contaminants, nitrate, and an as yet undetermined amount of sulfate. The capture of volatile contaminants in the off-gas treatment system may also be irreversible. The quantity and characteristics of the off-gas treatment residuals are reported in Section 5.4. The generation of glass is an irreversible effect. Transforming the glass into another nonvitreous product would be nearly impossible. The immobilization of contaminants in the glass matrix can be considered as an irreversible process. The dissolution rate of silica glass is so very slow that glass grains may exist for millions of years, while retaining the original contaminants. Glass is resistant to chemical attack by most natural solutions. Disposal of the vitrified glass in a cell is not considered irreversible in that the material could be exhumed in the future.

5.4 Type and Quantity of Residuals

Treatment of the Weldon Spring wastes will produce residuals that must be addressed as part of disposal planning. The type and quantity of treatment residuals and the sources and magnitude of the associated remaining risks are described in the following subsections. In addition to processing residuals, there are other residuals that will result from site activites. A brief discussion of these residuals follows.

As discussed in Section 4, excavation and volume reduction activities are common elements of the alternatives under consideration. Consequently, the level of remaining risk due to these two activities is the same for both the CSS and vitrification alternatives.

Excavation activities will generate contaminated tires, used equipment parts, and engine, transmission, and rear-end gear box fluids as residuals that must be treated and/or managed for disposal. A greater concern is the ability to remove all material with contaminant concentrations above a given action limit. Excavation equipment will be selected to remove the contaminated media based on selectivity and removal capabilities. Backhoes can dig deeply downward and can selectively remove 1-foot- to 1.5-foot-thick benches of material. Front-end loaders can remove benches of material only 6 inches thick. Radiometric field instrumentation will be used during all excavation activities. These instruments will allow detection and removal of radiometrically contaminated media to removal criteria levels, minimizing residual risks.

Volume reduction activities will also result in residuals to be managed. The principal treatment residual generated during volume reduction, other than the sized material, will be the contaminated dust from collection hoods, facility baghouse, and final filters used to capture dust. For some volume reduction activities, contaminated process water will require management.

Contaminated personal protective equipment (PPE) will be generated during all remedial action activities. It is estimated that more than 5,000 cubic yards of used PPE will be barreled and compacted. This residual material must also be managed for disposal.

5.4.1 Alternative 1 - No Further Action

Approximately 135 cubic yards per year of residues will be generated by the quarry water treatment plant and 135 cubic yards per year generated by the site water treatment plant, assuming operation at 90% efficiency. These residues will be processed through the CSS or vitrification treatment facility.

5.4.2 Alternative 6A - Removal, Chemical Stabilization, and On-site Disposal

Approximately 427,200 cubic yards (619,400 tons) of CSS-treated product will be produced. Virtually no other residuals will be generated by this technology. Washdown water and sediment will be recycled to the pug mill. The only filters used during the implementation of this alternative are those used on the fly ash and cement storage silos. These filters will likely be disposed of into the on-site cell, but will likely not be contaminated. A filter may be included in the building which houses the pug mill; however, since all the equipment is sealed and all the wastes are wet, dust generation will be minimal. Any contaminated filter will be disposed of within the cell without further treatment. The filters may be placed to allow encapsulation by subsequently poured CSS product.

Under this alternative, 500 cubic yards of residues will be generated by the quarry water treatment and 3,100 cubic yards of residues will be generated by the site water treatment plant over a plant operating life of 10 years. These quantities are included in the above figures.

5.4.3 Alternatives 7A, 7B and 7C - Removal, Vitrification, and On-site or Off-site Disposal

Treatment residuals resulting from the use of a fossil fuel-heated ceramic melter will consist of the 102,500 cubic yards of fritted glass product and the off-gas treatment wastes. Because it is assumed that the glass product will be placed in an on-site or off-site engineered disposal cell, the following discussion centers on the off-gas treatment system residuals.

The off-gas treatment residuals generated during vitrification processing are (1) quench/scrubber liquid residuals (i.e., blowdown) and (2) final filtration equipment residuals (i.e., used HEPA filters). The quantities of treatment residual solids were calculated based on an annualized 125-ton-per-day process. All values are mass balance estimates based on a preliminary conceptual-level off-gas treatment system design and on vendor/literature gross estimates of melter-to-off-gas emission factors.

Pilot testing of the off-gas treatment system is required to accurately quantify treatment residuals requiring disposal. Scrubber residual quantities were estimated based on mass balances using worst-case (high residual quantities), best-case (low residual quantities), and expected-case (expected residual quantities) scrubber efficiencies and absorbing compounds. The final filtration residual quantities are based on expected-case scrubber efficiencies. Conservatively estimated air emissions, however, will not necessarily correspond to any of these "residual" cases.

- <u>Scrubber Liquid Residuals</u>
  The off-gas treatment system scrubbers consist of a primary quench scrubber and a secondary aerosol/acid-gas scrubber. Solids separated from the primary quench scrubber blowdown slurry will be recycled back to the melter for vitrification. The remaining liquid will be recycled back into the scrubber after treatment. Slurry from the secondary aerosol/acid gas scrubber blowdown will also require separation. These solids will require disposal as contaminated waste because the elevated concentrations of volatile metal prohibit recycling back into the melter. In both scrubbers, lime or limestone are added to the liquid during the treatment process, significantly increasing the quantity of scrubber blowdown solids requiring disposal.

- <u>Final Filtration Equipment Residuals</u>
  Final filtration equipment will be designed primarily to control radionuclide and volatile metal particulate emissions. Pre-filters and HEPA filters will be used to reduce these emissions. The pre-filters will be of a cleanable fabric type, from which

all captured particulates will be recycled back into the melter, or of a deep-bed filter type, which may also be recycled back into the melter. The HEPA filters will require disposal at annual intervals. An alternative to direct disposal of the HEPA filters is to also reprocess them into the melter. This option will result in a lower overall volume of residuals requiring disposal and in a more secure physical form for disposal of the radionuclides.

- <u>Treatment Residual Quantities</u>

  The following scrubber residual quantities are presented using best-case, worst-case, and expected-case scenarios for scrubber efficiencies and for absorbing compounds used. Changes in either the scrubber efficiencies or the type of absorbing compounds significantly affect the quantities of scrubber residuals. Final filtration residual quantities reflect expected-case scrubber efficiencies.

  - <u>Scrubber Residuals - Worst Case</u>

    The worst-case scrubber residual quantity given below is based on a case where (1) the primary quench scrubber is operating at low efficiency, and the secondary aerosol/acid gas scrubber is operating at high efficiency and (2) lime ($Ca(OH)_2$) is the absorbing compound added to the liquid in both scrubbers. All residuals generated by the primary quench scrubber will be recycled back into the melter. The aerosol/acid-gas scrubber will generate approximately 837 lb/hour of residuals requiring disposal as contaminated waste. In this worst-case scenario, the aerosol/acid gas scrubber will generate approximately 3,666 tons/year of scrubber treatment residuals requiring disposal.

  - <u>Scrubber Residuals - Best Case</u>

    The best-case scrubber residual quantity given below is based on a case where (1) the primary quench scrubber is operating at high efficiency, and the secondary aerosol/acid gas scrubber is operating at low efficiency and (2) limestone ($CaCO_3$) is the absorbing medium in both scrubbers. In this scenario, the aerosol/acid gas scrubber will generate 32 lbs/hour of treatment residuals requiring disposal. In this best-case scenario, the aerosol/acid gas scrubber will generate approximately 140 tons/year of scrubber treatment residuals requiring disposal.

- Scrubber Residuals - Expected Case

  The expected-case scrubber residual quantity represents (1) the most likely attainable scrubber efficiencies for both primary and secondary scrubbers and (2) the use of limestone ($CaCO_3$) as the absorbing compound in both scrubbers. This scenario will produce an estimated 137 lbs/hour of treatment residuals that will require disposal. In this expected-case scenario, the aerosol/acid-gas scrubber will generate approximately 600 tons/year of scrubber treatment residuals requiring disposal.

- Final Filtration Residuals

  Preliminary design of each vitrification unit includes a 15,000-cfm blower, a pre-filter, two primary HEPA filter banks, and a secondary HEPA filter bank. Cleanable fabric, or disposable deep-bed fiber, pre-filters will capture an estimated 99% of the particulates exiting the secondary aerosol scrubber. All of these solids (0.35 to 2.3 lbs/hr) will be recycled back into the melter for vitrification. Primary and secondary HEPA filters downstream of the pre-filters will collect most of the remaining particulates. These filters require up to 7 years to become fully loaded, based on average scrubber efficiencies. It is conservatively estimated that the primary and secondary HEPA filters will be replaced annually to maintain a high margin of safety.

  Primary and secondary HEPA filter banks will hold an estimated total of forty-five 1,000-cfm filters per vitrification unit. This represents a total of 90 HEPA filters that will require disposal annually. It is assumed that all of these filters can be recycled back into the melter for disposal.

  If not recycled, the quantity of HEPA filters that will require disposal is estimated to be 2,880 pounds per year (13.3 yd^3/year).

Extreme caution must be exercised in extracting solids disposal quantities from this study prior to pilot testing. Because melter emissions were based on one test and scrubber, efficiencies were selected to conservatively estimate air emissions, and are therefore non-conservative for scrubber solids disposal, solids disposal quantities could be significantly different from reported values.

Concentrations of contaminants in scrubber residuals using worst-case (highest residual quantities), best-case (lowest residual quantities), and expected-case (expected residual quantities) scrubber efficiencies are presented in Table 5-12.

Concentration of contaminants in final filtration equipment residuals listed in Table 5-13 are for primary and secondary HEPA filters which will be changed annually. Expected-case scrubber efficiencies are assumed. These concentrations are base on an estimated 90 HEPA filters requiring disposal for a total weight of 2,880 pounds per year (13.3 yd^3/year).

TABLE 5-12 Concentration of Contaminants in Scrubber Residuals

Contaminant	Worst-Case* (mg/kg)	Best-Case* (mg/kg)	Expected-Case* (mg/kg)
Metals/Metalloids			
Lead	383	3,254	1,985
Arsenic	1,977	19,292	10,555
Cadmium	106	1,059	568
Selenium	622	16,197	3,793
Mercury	37	1,926	182
Copper	16	205	71
Nickel	19	235	82
Chromium	2	26	9
Vanadium	164	2,148	749
Zinc	111	1,477	512
Calcium\Sodium Salts			
Sulfites/sulfates as $CaSO_4 \cdot 2H_2O$	36,500	417,000	157,000
Chloride as $CaCl_2$	130	3,400	760
Fluoride as CaF_2	20	190	80
Nitrate as $Ca(NO_3)_3$	143,000	0	456,000
Carbonate as $CaCO_3$	730,000	25,000	28,000
Radionuclides (pCi/kg)			
U-234	$2.2 \times 10^{+4}$	$2.9 \times 10^{+5}$	$1.0 \times 10^{+5}$
U-238	$2.6 \times 10^{+4}$	$3.4 \times 10^{+5}$	$1.2 \times 10^{+5}$
Th-230	$4.2 \times 10^{+5}$	$5.5 \times 10^{+6}$	$1.9 \times 10^{+6}$
Th-232	$4.9 \times 10^{+3}$	$6.4 \times 10^{+4}$	$2.2 \times 10^{+4}$
Ra-226	$2.2 \times 10^{+4}$	$2.9 \times 10^{+5}$	$9.8 \times 10^{+4}$
Ra-228	$5.3 \times 10^{+3}$	$6.9 \times 10^{+4}$	$2.4 \times 10^{+4}$
Pb-210	$1.4 \times 10^{+6}$	$1.2 \times 10^{+7}$	$7.4 \times 10^{+6}$
Po-210	$5.1 \times 10^{+4}$	$6.6 \times 10^{+5}$	$2.3 \times 10^{+5}$

Worst-case = Highest residual quantities
Best-case = Lowest residual quantities
Expected-case = expected residual quantities

TABLE 5-13 Concentration of Contaminants in Final Filtration Residuals

Contaminant	Concentration
Metals/Metalloids (mg/kg)	
Lead	436
Arsenic	2,317
Cadmium	125
Selenium	833
Mercury	0
Copper	3
Nickel	3
Chromium	.4
Vanadium	32
Zinc	22
Calcium/Sodium Salts and Other Solids (mg/kg)	7,336
Radionuclides (pCi/kg)	
U-234	$4.27 \times 10^{+3}$
U-238	$4.94 \times 10^{+3}$
Th-232	$8.11 \times 10^{+4}$
Th-232	$9.46 \times 10^{+2}$
Ra-226	$4.19 \times 10^{+3}$
Ra-228	$1.01 \times 10^{+3}$
Pb-210	$1.62 \times 10^{+6}$
Po-210	$9.76 \times 10^{+3}$

Note: Includes HEPA filters only if not recycled. Pre-filter solids are assumed recycled.

The residuals generated during off-gas treatment will present a minimal threat upon disposal into a cell, either on site or off site. It may be necessary to use a small, probably portable, CSS treatment facility to process the treatment residuals prior to transport and disposal.

As with Alternative 6A described previously, 3,600 cubic yards of residues will be generated during the 10-year operating life of the site and quarry water treatment plants and are included in the vitrification plant feed.

6 ADEQUACY AND RELIABILITY OF CONTROLS

The following discussion addresses the likelihood that the treatment technologies under consideration will meet required efficiencies or performance specifications. Included in this discussion are the type and degree of long-term management required, the requirements for long-term monitoring, the operation and maintenance functions performed, difficulties and uncertainties associated with long-term operation and maintenance, the potential need for replacement of technical components, the degree of confidence that controls can adequately handle potential problems, and the uncertainties associated with land disposal of residuals and untreated wastes.

6.1 Alternative 1 - No Further Action

The long-term reliability of the containment systems in place at the temporary storage area (TSA), material staging area (MSA), and the site and quarry water treatment plants will be low. If maintenance is not provided beyond the 10-year design life, the systems are at risk of failure caused by degradation of the synthetic liners from ultraviolet light, deterioration of the subbase from settlement, operational stresses, wind abrasion, freeze—thaw cycles, and erosion from direct precipitation and runoff. These systems are not designed to provide long-term protection. The performance of these containment systems relies on site security and the institutional controls which are currently in place.

Selection of the no further action alternative would mean that existing source areas, including the raffinate pits, would remain unabated and would continue to be a source of contaminant migration. Also remaining would be a potential for raffinate pit dike failure and direct release of contaminants to the surrounding environment.

6.2 Alternative 6A - Removal, Chemical Stabilization, and On-site Disposal

Pug mill-mediated chemical solidification/stabilization (CSS) technology is a well established and understood process. The described CSS treatment system can be designed to meet process efficiencies and performance specifications. All of the equipment used in the postulated CSS system have well documented performance histories. The system uses standard, readily available equipment thus minimizing any concerns regarding replacement of technical components. In addition, the system layout is relatively uncomplicated and readily accessible for repair and parts replacement. No difficulties are anticipated with long-term maintenance.

Operating efficiency will be greatly aided by the fact that the CSS system will only operate 1 shift per day, 5 days per week. The scheduled downtime will allow repairs to be performed off shift without impacting the productivity of the system. The system described in this alternative is designed to operate at the budgeted throughput with time allocated for repairs during operating hours. A 15% overdesign capacity is also incorporated. In addition, it has been shown that a CSS plant, after a shakedown period, can periodically exceed its design productivity.

Controls associated with the CSS treatment facility include proceduralized, systematic operations with key monitoring and sampling points to ensure consistent product quality; strict operating specifications for feed preparation; and monitoring and engineering controls in place to detect and control cement and reagent emissions.

The CSS alternative involves disposal of treated and untreated wastes in an UMTRA-type engineered cell incorporating the components of a RCRA disposal facility. The individual controls within the disposal facility containment system include a double liner, a leachate collection and removal system, a leak detection system, a radon barrier, an infiltration barrier, a cover and institutional controls such as fencing and deed restrictions. These controls provide some measure of redundancy and are designed to perform as an integrated system. If individual components fail, the redundancy of controls will ensure that the system remains intact unless a combination of failures occurs, which is very unlikely.

Settlement of the waste within the cell should be minimal due to the structural strength of the grout-like CSS product and the compacted soil-cement waste. Previous bench-scale tests indicated that CSS products generated from raffinate sludge had unconfined compressive strength values into the hundreds of pounds per square inch; values far exceeding the required 50 psi value. Void spaces can be almost eliminated as large pieces of debris can literally be grouted into place, minimizing waste settling in the cell.

Long-term maintenance of the cell cover and leachate collection system and continuation of groundwater monitoring will be required. Ongoing treatment of leachate in the water treatment plant may be required over the short term. Leachate production should cease, however, once the cell is closed and water introduced during construction has drained.

Although there are uncertainties associated with land disposal of radiologically contaminated materials, at present there are no other reasonable alternatives. These uncertainties are minimized by treating the contaminated wastes and placing them in an engineered disposal facility such as that proposed for the Weldon Spring wastes.

6.3 Alternatives 7A, 7B and 7C - Removal, Vitrification, and On-Site or Off-Site Disposal

It is probable that the fossil fuel-heated ceramic melter (FFHCM) system under consideration will meet required process efficiency and performance specifications. Two parallel, yet independent, melter system trains are planned. Consequently, if one system is down for repairs, the other system will continue to operate. Furthermore, the equipment was sized to allow for sufficient scheduled downtime to perform both routine maintenance and major repair activities. An additional 15% overdesign throughput capacity was also incorporated into the system to help ensure throughput demands are met. The use of the fossil fuel as a heat source also allows immediate modification of the melter operating temperature. The ability to quickly change melt temperatures will aid in controlling variability in melt viscosity and phase immiscibility due to chemical variation in the feed. Use of well established grinding technology to prepare the feed will also assist in maintaining the designed melter throughput. The proposed melter is quite similar to those used in the commercial glass industry. Glass industry melters typically maintain 90% operating efficiency over years of operation and often achieve or exceed the design production capacity.

Performance of the off-gas treatment system is more difficult to accurately forecast. The proposed equipment, while maintaining 90% availability in joule-heated ceramic melters, does not have a long enough history in FFHCM applications to allow definitive statements to be made regarding its probable performance. During pilot-scale testing, the off-gas system could be optimized and designed to allow 90% availability.

Potential need for replacement of technical parts is not a concern. Time has been allotted to repair the vitrification system and relatively common parts and repair techniques will be used. The ability of FFHCM technology to handle a wide range of waste feed, the ability to rapidly control temperature, and the use of a sophisticated and effective off-gas treatment system with the capability of recycling off-gas for further treatment allows a reasonable degree of confidence that the proposed system can meet performance specifications with minimal operational difficulties.

Difficulties associated with the long-term maintenance are related to the disposal cell, not with the melter or the vitrified product, and are similar regardless of an on-site or off-site cell location. As previously described, this alternative uses separate engineered disposal cells for the vitrified and the untreated wastes. Long-term monitoring of the vitrified and untreated waste disposal cells will focus on cell cover integrity and groundwater monitoring. Operation and maintenance functions will emphasize cell cover repair due to erosion and settling. Settling of the wastes within the cell may be exacerbated by incomplete filling of voids around large pieces of debris.

The durability and leach resistant characteristics of the vitrified material provide a basis for constructing a disposal facility with reduced engineering controls compared to those required for the CSS-treated wastes in Alternative 6A. The proposed cell for vitrified waste will include a bottom liner consisting of compacted in-place soils (compacted clay) and a cover system similar to the combination cell used to contain CSS-treated wastes. The fritted product will likely exhibit friction angles that may result in slope stability concerns. Therefore, it is proposed to construct the cell below ground to minimize those concerns. In addition, an LCRS is not required since the glass product is essentially inert, and infiltrating water is not likely to pick up high concentrations of contaminants. Since an LCRS is not required, associated maintenance or treatment of leachate is also not required. Reduced cover maintenance is also anticipated, since the vitrified material will be relatively homogeneous so differential settlement will be of less concern and erosion will be reduced due to the flat cover slope.

The cell proposed for containment of the untreated wastes will be very similar to the combination cell described in the CSS alternative. The only differences are the use of a single liner instead of a double liner and the elimination of the leachate detection system. Since all highly contaminated materials will be contained in the vitrified-waste cell, this facility does not require the redundancy provided by the second liner and leachate detection system. These deletions will reduce the adequacy and reliability of the disposal facility controls; however, overall reliability is not compromised considering the waste form. Monitoring and maintenance will be similar to that described for the CSS alternative. Also similar to the combination cell, the facility will be constructed above ground, which facilitates monitoring and maintenance of the cell.

7 IMPLEMENTABILITY

Implementability involves both the technical and administrative feasibility of executing a technology. Aspects of implementability to be considered during evaluation of a technology include the availability of necessary equipment and skilled workers, and the availability of services and materials that may be required for implementation.

7.1 Availability of Prospective Technologies

This subsection describes the availability of the prospective technologies by alternative, the number of vendors offering the technology, and whether additional technology development is required prior to implementation.

7.1.1 No Further Action

Treatment technologies will not be used. Standard environmental monitoring of the site will continue, and maintenance of the MSA and TSA will be required.

7.1.2 Chemical Solidification/Stabilization

The proposed pug mill-blended CSS technology is an established process that has been demonstrated to be effective for hazardous wastes. CSS technology does not require further development before it can be implemented because it is an EPA-accepted technology. This technology is readily available for full-scale use as illustrated by the following tables. CSS technology has been implemented at the sites listed in Table 7-1 and 7-2 where the volume of waste to be treated has exceeded 100,000 cubic yards.

TABLE 7-1 Wastes Treated with CSS Technology

Site	Contaminants	Treatment Volume (yd^3)
Marathon Steel, AZ	Metal sludges	150,000
ENRECO, KY	Organic sludges	180,000
N.E. Refinery	Organics and metals	100,000
Vickery, OH	Acid and organic sludges	235,000

TABLE 7-1 Wastes Treated with CSS Technology (Continued)

Site	Contaminants	Treatment Volume (yd^3)
Gurley Pit, AR	Organics and metals	430,000
Douglassville, PA	Organics and metals	250,000

The waste materials being treated at the Marathon Steel, N.E. Refinery, and Douglassville sites are similar to waste at the Weldon Spring site. The details of these CSS case studies are presented in Table 7-2.

Metal sludges are also being treated at several other sites, but the treatment volumes are less than 100,000 cubic yards.

7.1.3 Vitrification

Fossil fuel-heated ceramic melters are widely used in the glass manufacturing industry. An estimated 95% of manufactured glass is processed using FFHCM technology. Consequently, the FFHCM technology used in the glass-making industry is in full-scale development. Fossil fuel-heated ceramic melters, available from the commercial glass manufacturing industry, could probably be modified to process the Weldon Spring site wastes. However, modification of the system to exceed the capabilities of the Vortec system would be difficult. It may be advisable, therefore, to use a system that already incorporates these modifications such as the Vortec system.

Adaptation of the FFHCM technology to the treatment of radioactive and chemically contaminated waste is currently only in the pilot-scale stage of development. FFHCM technology has not been used for full-scale remediation of any chemically contaminated or radioactive wastes. Pilot-scale plants, with throughput capacities in the range of 25 tons of glass per day, are available. FFHCM systems adaptable for use at Weldon Spring are also available. Increasing the throughput capacity of these pilot-scale plants to the capacity necessary for the

TABLE 7-2 CSS Case Studies

Site/ Contractor	Contaminant (Concentration)	Treatment Volume (yd^3)	Physical Form	(Y/N)	Chemical Pretreatment Binder	Percentage Binder(s) Added	Treatment (Batch/ Continuous In Situ)	Disposal (On-site/ Off-site)	Volume Increase (%)	Scale of Operation
Marathon Steel Phoenix, AZ Silicat, Tech.	Pb, Cd	150,000	Dry - landfill	N	Portland cement and silicates (Toxsorb)™	Varied 7-15% (cement)	Concrete batch plant	Landfill	NA	Full scale
Unnamed Kentucky ENRECO	Vinyl chloride Ethylene	180,000	Sludges, variable	Y	Portland cement and proprietary	Varied 25 +	In situ	On-site (2 secure) cells built on site)	>7-9%	Full scale
N.E. Refinery ENRECO	Oil sludges, Pb, Cr, As	100,000	Sludges, variable	N	Kiln dust (high CaO content)	Varied, 15-30%	In situ	On-site	> Varied, ~20% average	Full scale
Vickery, OH Chemical Waste Management	Waste acid, PCBs (<500 ppm), dioxins	~235,000	Sludges (viscous)	Y	Lime and kiln dust	~15% CaO ~5% kiln dust	In situ	On-site (TSCA cells)	> ~9% +	Full scale
Gurley Pit, AR	PCBs and organics	432,470[a]	Soil					On-site		
Douglassville, Pennsylvania HAZCON	Zn, 30-50 ppb Pb, 24,000 ppm PCBs, 50-80 ppm Phenol, 100 µg/l Oil and grease	250,000[a]	Various soils/ sludges	N	Portland cement and proprietary	NA	Batch	NA	NA	Pilot scale

[a] Total volume on site
NA - Data not available

timely processing of Weldon Spring site wastes (125 tons of glass per day) should be achievable with minimal difficulty. The throughput necessary to meet the project schedule requires a relatively modest scale-up of the existing pilot-scale plants.

The preliminary conceptual FFHCM plant discussed in Section 4 also requires a pretreatment circuit to reduce the feed material to an acceptable size. The technology required for the proposed pretreatment circuit is readily available.

The off-gas treatment system for the FFHCM, however, is not well defined. Although off-gas treatment systems are used to process off-gas from joule-heated ceramic melting of high-level radioactive wastes, additional conceptual design, and bench- and pilot-scale testing will be required to define the optimal off-gas treatment equipment for the FFHCM system suggested for use at the Weldon Spring site. An off-gas treatment system optimized for the Weldon Spring Site wastes will need to be designed regardless of the melter system chosen. Although the off-gas treatment system will utilize standard and readily available components, additional conceptual design and testing is needed to determine the specific equipment and configuration. It is likely that an off-gas treatment system can be designed to meet virtually any regulatory criteria. However, as complexity increases, operational problems could develop which could impact scheduled throughput of feed. A limited history and database for this application of an off-gas treatment system means that a significant amount of work will be initially required in getting the system to work. Eventually, system optimizations can be formulated and completed.

Vitrification, using joule-heated ceramic melters, is commonly used to treat high-level radioactive wastes. Table 7-3 lists, by location, the quantities of high-level radioactive waste processed by joule-heated ceramic melters. Fifteen vendors have been identified for electrically based (joule-heated ceramic melters, plasma arc torch and in situ) vitrification technologies.

TABLE 7-3 High-Level Radioactive Waste Processed by JHCM

Location	Waste Type	Vitrified Quantity
Hanford, WA	Transuranic-contaminated soil	450 tons
Arnold AFB, TN	Petroleum-oil lubricants and heavy metal constituents	15 tons

TABLE 7-3 High-Level Radioactive Waste Processed by JHCM (Continued)

Location	Waste Type	Vitrified Quantity
PAMELA Plant, Mol, Belgium	High-level liquid waste	350 tons
PNL, Richland, WA	Radioactive	5 tons
Sellafield	High-level liquid waste	not reported
Savannah River Plant, SC	High-level liquid waste	30,000 gallons (to be treated)
West Valley Demonstration Project, NY	High-level liquid waste	88 metric tons

7.2 Availability of Equipment and Specialists

This subsection discusses the availability of the equipment and specialists required to implement the proposed treatment technologies. Equipment and experienced employees should be readily available for the CSS alternative. Although equipment for the vitrification alternative is available, an experienced work force may be more difficult to locate due to the limited use of vitrification technology in treating radioactive or chemically contaminated wastes.

7.2.1 Alternative 1 – No Further Action

Light construction equipment will be required for maintenance of the MSA, TSA, and other site facilities. Specialist will be required for environmental monitoring, and laborers needed for maintenance activities. Trained operators for the water treatment plants will be required.

7.2.2 Alternative 6A – Removal, Chemical Solidification, and On-Site Disposal

The proposed pug mill-mediated CSS technology employs readily available and commonly used equipment. In addition, the overall relatively standard design of the system will allow for efficient construction and operation. A large amount of ASTM Class F fly ash and Type II Portland cement will be consumed during the CSS processing of the Weldon Spring wastes. Three Portland cement vendors were contacted to detemine adequacy of local cement supplies. These vendors are located within a few hundred miles of the site. Each vendor assured that adequate cement would be available. A local power company source also indicated that adequate ASTM Class F fly ash could be supplied.

7.2.2.1 Equipment. Analysis of the CSS system equipment indicates that only very common equipment, widely used in the construction, precious metal heap leaching, and hazardous waste remediation industries, is included. Consequently, construction of the proposed system will not be limited by the availability of equipment. The CSS equipment list is shown in Table 7-4.

TABLE 7-4 CSS Equipment List

Item	Description	Total Cost ($)
T-101	Slurry/Mixer Tank (25 HP)	65,000
T-102	12,650 ft³ Cement Silo	77,500
T-103,104,105,106	15,000 ft³ Fly ash Silos	265,000
A-101	20 CFM/150 psi Air Compressor (1.5 HP)	3,500
C-101	115 foot Horizontal Screw Conveyor (30 HP)	25,000
C-102	60 foot 25° Screw Conveyor (30 HP)	20,000
M-102	Mixer/Product Tank (75 HP)	75,000
S-101	Sludge/Slurry Pump (75 HP)	85,000
P-101	Pug Mill (100 HP)	40,000
A-101	Apron Feeder (15 HP)	7,500
F-101,102,103,104,	Volumetric Feeder (1.5 HP)	17,500
V-101	Vibrating Screen (5 HP)	12,000
H-102	Live Bottom Bin (50 HP)	35,000
T-107	Truck Dump	15,000
	Building (60' x 40')	108,000
	Cat. 966E Front-End Loader	178,000
	TOTAL	1,029,000

7.2.2.2 Manpower. The proposed CSS alternative will require an estimated 3.5 general laborers to operate the CSS facility. A minimum of 2 years of related industrial work experience will be required; however, specialized, formal training is not necessary. An estimated 2.5 maintenance personnel are required to repair and maintain the equipment. Journeyman-level machine repairman, millwright, electrician, plumber specialties are required. One and one-half equivalent supervisors, 1.25 laboratory, and 1.5 administrative employees will also be required for plant operation. These employees will also be required to have a minimum of 2 years of related industrial experience. All employees involved with actual plant operation will be required to complete a 40-hour OSHA-approved training course (10 CFR 1910.120), as well as required 8-hour annual refresher classes.

The effective and efficient operation of any relatively complex technical system is dependent on the capability and experience of the operation supervisor. Although it will not be necessary for this individual to have a civil or process technology engineering degree, related project experience is required. The ideal candidate will have experience in the CSS treatment of hazardous wastes. The EPA regards CSS technology as a proven remedial treatment and has approved its use at 62 NPL sites (Chemical Engineering Progress 1991). Use of this technology at NPL and other sites will have developed an experienced pool of supervisors from which a candidate can be drawn.

It is important to note that operation of the proposed CSS facility is not anticipated to be very difficult. Once further testing has optimized a reagent to waste blend the primary role of the plant supervisor/superintendent is to minimize deviation from the proposed blend during operation. Continual bench-scale testing of future processed wastes will help determine modifications to the base case blend to optimize product quality in terms of contaminant immobilization and compressive strength. Variations in feed characteristics will likely necessitate some operational responses, such as perhaps adding in reagents to accelerate grout set time, modification of the cement/fly ash blend or additive ratio, or the use of other CSS reagents such as bentonite, zeolites, or ion exchange resins to yield an acceptable product. The ideal supervisor will understand when and how operational modifications can correct potential product quality flaws and maintain product quality and throughput.

The wide use of pug mills in a variety of applications will have developed an relatively large pool of operators and maintenance personnel from which to draw. Importantly, the relatively uncomplicated nature of the CSS system will not require very experienced or sophisticated operators to ensure adequate product quality and scheduled throughput to be achieved. To achieve adequate product quality it will be vital that the operators strictly adhere to the operation QA/QC procedures. As detailed above, a more limited workforce of supervisors should be available.

7.2.3 Alternatives 7A, 7B and 7C – Removal, Vitrification, and On-Site and Off-Site Disposal

7.2.3.1 Equipment. As shown in Table 7-5, the vitrification system is comprised of pretreatment circuits, the melter assembly, and an off-gas treatment system.

TABLE 7-5 FFHCM Equipment List

Description
Dewatering equipment
Raffinate Sludge Pretreatment
Soil and Clay Bottom Pretreatment
Feeding and Blending Equipment
Vitrification/Product Handling
Off-Gas Treatment System
Buildings

The availability of each of these component devices is discussed below.

- **Dewatering System**
  All of the equipment required for dewatering is readily available from vendors and is widely used in commercial process plants.

- **Pretreatment Circuits**
  All of the equipment used in the pretreatment circuits is readily available from many vendors. This type of equipment is widely used in the mining industry and can be easily and quickly obtained.

- **Melter System**
  The Vortec, Inc. fossil fuel-heated ceramic melter is available for use as the vitrification technology. Vortec is able to manufacture a production-level melter capable of processing the required throughput of wastes. Presently, a 25-ton-per-day system is available and Vortec personnel have repeatedly stated that 100-ton-per-day melter systems can be readily constructed. Additionally, it may be possible to

modify fossil fuel-heated ceramic melters used in the glass industry to process the Weldon Spring site wastes since an estimated 95% of manufactured glass employs this technology. This modification could be difficult and would not likely yield a system as effective as the Vortec melter.

- **Off-Gas Treatment System**
  The off-gas treatment system will use standard equipment that is readily available. However, further conceptual design and bench-, and pilot-scale testing of the system will be required prior to installation. Vendors specializing in off-gas treatment system design and construction are available to assist with system development and testing. Whereas the off-gas treatment system will utilize common devices, the selected devices and their configuration have yet to be defined, tested, and optimized.

7.2.3.2 Manpower. The total manpower required to operate and maintain the physical pretreatment and melting circuits is summarized below in Table 7-6:

TABLE 7-6 Manpower Requirements for Vitrification Facility

Circuit	Type of Personnel	Number Required
Pretreatment	Supervisor	1
"	Operators	2
"	Maintenance	2.5
"	Equipment Operators	2
Melter	Process Engineer	1
"	Operators	4
"	Maintenance	4.5
"	Laborers	4

A process engineer will be in charge of the operation of both the physical pretreatment and melting circuits and also act as the supervisor for the melting circuit. This engineer will be a degreed engineer with a chemical, metallurgical, or ceramic background.

The melter circuit will operate 3 shifts per day, 7 days per week. One operator is required for each shift to monitor melter operation to assure that the melter is operating at the required temperatures and production rates and that emissions are in compliance. One maintenance person is required per shift to conduct required regular maintenance and to effect repairs when necessary; an additional maintenance person on a single shift will split his/her time between the pre-treatment and melter circuit. One laborer is required per shift to collect shift product samples, move product collections bins, and assist maintenance personnel as necessary.

A supervisor is required to oversee both pretreatment circuits. This individual will have previous materials sizing/grinding experience; a college degree in a related discipline is desirable but not necessary. An operator is assigned to each individual pretreatment circuit: raffinate sludge or quarry soil and clay bottom. These operators will monitor the operation of their respective circuits to assure equipment is operating at required rates and up to specification. Two maintenance personnel will work together to maintain all three circuits and affect repairs when necessary. The two equipment operators will operate the loaders which will be used to feed the quarry soil or the clay bottom to the circuit. These operators will also be available to assist the maintenance crew or with operations at the melter.

This work force will be supported by laboratory technicians and administrative personnel. The operators and maintenance personnel will require related industrial work experience. The number of operators and maintenance personnel with previous experience in the vitrification of hazardous waste is limited, but these personnel could be drawn from the commercial glass-making industry or the high-level radioactive waste vitrification industry. Operators and repair personnel may also potentially be drawn from the incineration industry, where experience in operating and maintaining the off-gas treatment system will be important. Locating operators and repairmen with previous vitrification experience will not be as critical as locating an experienced supervisor/superintendent.

There are no degree requirements for operators and maintenance personnel -- only adequate industrial work experience. Maintenance personnel will be required to have journeyman-level training as machine repairmen, millwrights, electricians, and plumbers.

As with any relatively complicated technical system a capable and experienced process engineer/superintendent will be critical in the efficient and effective operation of the FFHCM. Locating a degreed engineer with both the appropriate educational background and experience may be difficult. Suitable candidates may be drawn from the glass industry, high level radioactive waste vitrification, or incineration industry. The lack of a full scale FFHCM unit for treating hazardous or low level waste has not allowed a large, well trained work force to develop. Vortec Corporation has experience in training their own operators and can assist in locating and training a qualified process engineer.

All workers will be required to have completed an OSHA-approved 40-hour hazardous waste training course. The vendors selected to design and construct the vitrification and off-gas treatment circuits will train the process engineer, the operators, and the maintenance technicians during the pilot-scale testing period and the shakedown period for the full-scale plant.

7.3 Ability to Construct and Operate

This subsection focuses on the difficulties associated with the construction and operation of the technologies. It is important to note that these two criteria do not equally apply to the activities associated with the different alternatives. For example, the facilities for both the vitrification and CSS alternatives can be easily constructed. The operational aspects of the two technologies is of greater significance. Conversely, whereas the disposal cell has minimal operational activities, its constructibility is of greater importance. The following discussion will therefore emphasize the ability to operate the two candidate technologies rather than their constructibility and the constructibility of the disposal cells rather than their operation.

7.3.1 Alternative 1 – No Further Action

No additional construction will occur under the no further action alternative. Institutional controls will be maintained and the water treatment facilities will continue to operate. The MSA, TSA, and water treatment plants have a design life of 10 years.

7.3.2 Alternative 6A – Removal, Chemical Stabilization, and On-site Disposal

Constructibility of the CSS facility will not pose any problems. Pug mills are routinely built as part of construction, mining, and hazardous waste remediation projects. All of the necessary equipment is readily available. The proposed pug mill-based system will likely be much easier to operate than the proposed vitrification plant. The CSS plant utilizes relatively simple and well understood equipment. Most of the operational concern will deal with maintaining an acceptable water content in the raffinate slurry and correctly metering reagents. Both activities should be accomplished with minimal difficulty.

Operational problems will undoubtedly arise during CSS treatment. However, an experienced supervisor/superintendent should be able to anticipate, recognize, and resolve these problems through operational responses. For example, grout setting times can be modified through the use of set accelerators or inhibitors. Bentonite or aggipulgite can assist with controlling variable water content, and zeolites, ion exchange reagents and chemical reagents can enhance contaminant immobilization. Use of these and other grout-modifying reagents can be optimized during on-going testing. It is anticipated that the CSS facility can reach design throughput in a matter of a few weeks, at which time optimization of the system will begin.

The optimization period for the CSS plant can be contrasted with the start-up period of the vitrification facility in that a large amount of effort will likely be required to start up the vitrification off-gas treatment system, whereas the CSS activities after start-up will be directed at improving productivity in an already functioning plant. A relatively short optimization period is the result of CSS technology having been established as a proven remedial method which has been used at 62 NPL sites (Chemical Engineering Progress 1991).

The CSS feed systems employ silo metering devices which deliver waste and reagents to a screw conveyor for transport to the pug mill. Thorough mixing of reagents will be ensured during screw transportation prior to blending with wastes. Proper calibration and monitoring during operation will ensure the specified waste-to-reagent blend and feed rate. These systems are typically trouble-free and reliable. Waste delivery and reagent consumption records will assist in the daily and weekly calibration and adjustment of the metering devices.

The pug mill is a relatively simple and trouble-free system. Visual monitoring of the CSS mixture in the pug mill and in the storage hopper will identify the need for upstream system adjustment or water addition at the pug mill. Because throughput is relatively fast, real time modifications can be made to the grout. Grout thought to have been improperly formulated could potentially be recycled to the system via the soil feed circuit. If it was not immediately possible to recycle misformulated grout to the CSS system, a strong set inhibitor could be added to the grout, such as sugar, to prevent setting prior to reprocessing. Similarly, a dissolved sugar solution could be added to the pug mill and product discharge system in the event of a power failure to prevent setting during reestablishment of electrical power or while switching to an on-site generator. A backup auxiliary generator would assure discharge of the grout mix in the event of a power failure. Soil processing will require careful water addition to allow full hydration of the soil-cement mixture. Visual monitoring of the product with direct addition of water to the pug mill should ensure a fully hydrated product. Additional water may be required to allow the pumping of the grout to the product holding tank. An excessively dry grout could tax the capability of the positive displacement pump, which transfers grout from the pug mill discharge to the holding tank. Careful and minimal water addition should decrease grout viscosity to facilitate pumping.

Pneumatic transferral of cement and fly ash from delivery trucks to storage silos is planned. This is the common transferral methods for these reagents. Separate manifolds for the cement and fly ash silos will allow transferral of one reagent should a mechanical failure in the other transfer system occur. Since these units operate off a simple air compression system, it is unlikely that this problems in this system will hamper facility operation.

Although the above discussion is not intended as a comprehensive operation response plan, it does provide insight into the types of simple yet effective activities that can be implemented to resolve potential operational problems. None of the response activities are very complex, and they will help ensure effective operation of the CSS plant.

The design and construction of the RCRA-type engineered cell is also well understood. Although somewhat harder to construct than a sanitary-type landfill cell, a RCRA cell can be efficiently constructed. Some additional studies would likely be necessary to determine optimal grout placement and compaction methods; however, these studies are related to site-specific optimizations.

7.3.3 Alternatives 7A, 7B and 7C - Removal, Vitrification, and On-Site or Off-Site Disposal

As stated above, the construction of the vitrification facility can be readily accomplished. Of greater significance is the ability to operate the system. The vitrification facility is composed of three separate systems: a pretreatment circuit; a melter; and an off-gas treatment system. The following discussion focuses on the operational aspects of each of these components.

7.3.3.1 Pretreatment Circuit. The pretreatment circuit uses readily available and well understood sizing reduction equipment which is very widely used in the mining industry. The operation of similar types of grinding circuits at many mines suggests that this component of the vitrification system will not pose significant operational problems. The proposed pretreatment circuit does not employ any unusual or untested sizing reduction techniques. The Weldon Spring site wastes are unlikely to pose any grinding problems, although this has not yet been tested. Sizing reduction and grinding technology has developed to the point where almost any grindability problem can be solved using available and tested equipment.

7.3.3.2 Melter System. The melter system, as designed by Vortec should not pose serious operational difficulties. The Vortec system is based on modification of commercial glass manufacturing melters. The experience derived from this parent technology will provide important insight into the operational complexity of the Vortec system. Glass melters often achieve 90% continuous availability, suggesting ease of operation once the system is optimized. Downtime is related to on-going preventive maintenance and repair.

The Vortec system can be designed to operate largely by computer. Operational experience gained by Vortec personnel, during pilot scale testing, suggests that a combination of computerized and human oversight of melter operation is optimal. Numerous thermocouples and heat detectors located strategically throughout the melter system continuously monitor temperatures. The use of fossil fuel as an energy source allows real time temperature modifications to be achieved. Refractory corrosion can be a problem with any vitrification technology. However, refractories with design lives of 5 years will be installed, which exceeds the anticipated duration of vitrification operation for the Weldon Spring site.

The lack of any actual full-scale operation of the Vortec melter system suggests that operational problems may develop during start-up that may impact the process schedule. However, it is likely that these problems can be solved by a capable supervisor\superintendent, assisted by Vortec personnel.

7.3.3.3 Off-Gas Treatment System. The components in this treatment system may cause the most significant operational problems for the vitrification alternative. Although the capabilities of the individual off-gas treatment components are known, the effects of linking multiple treatment components together for an FFHCM system is less well established. Complex off-gas treatment trains have been built and operated effectively for joule-heated ceramic melters (JHCM) processing high-level radioactive wastes. These systems use many of the same components that are likely to be used in the proposed FFHCM system. However, the uniformity of the high-level radioactive waste feed and the lesser quantity of off-gas generated by JHCM units simplifies the off-gas treatment system compared to the system that would be needed to process the Weldon Spring site waste gases.

The lack of operational data pertaining to full-scale FFHCM off-gas treatment hinders estimation of difficulties that would be encountered with the proposed system. There is a concern that a system consisting of a complex train of treatment components could lead to extreme operational complexity. Moreover, effects from failure of individual components could exacerbate an otherwise insignificant problem in a downstream device resulting in a major operational problem.

It is likely that additional design effort will result in a system that can adequately treat the off-gases to within the regulatory limits. Although conceptual design studies usually emphasize a worst-case scenario when there is an absence of data, as is often the case with FFHCM off-gas treatment, extensive testing will still be required to determine the effectiveness of the treatment system. The combination of further design effort and extensive testing may indicate that treatment of the Weldon Spring site waste gases will not be as difficult as presently anticipated and may only require a relatively simple and easily operated system.

7.4 Reliability of the Technology

The following discussion addresses the reliability of technology and the likelihood that technical problems will lead to schedule delays. Technical problems that are most likely to occur are described, along with the types of failures and the consequences of those failures.

7.4.1 Alternative 1 – No Further Action

No treatment technologies will be used.

7.4.2 Alternative 6A – Removal, Chemical Solidification/Stabilization, and On-site Disposal

The proposed CSS system utilizes well understood technology. It is not anticipated that technical problems will arise during operation that will impact the schedule. Further bench- and pilot-scale studies will help optimize the system to minimize start-up problems. The operating histories for similar systems indicate that these systems typically have very little unscheduled downtime. Importantly, by operating only one shift per day, five days per week, time is available during off-hours to perform preventive maintenance repairs and equipment replacement. In the event that a temporary system failure does occur, time is also available to operate on an overtime basis to meet scheduled throughput requirements.

Two types of failures could occur due to technical problems related to CSS treatment: failure of the treated product to pass TCLP criteria and a treated product with an unconfined compressive strength less than 50 psi. Inadequate compressive strength problems may be caused by excess water in the raffinate sludge feed. This problem could be resolved either by adding in more reagent, specifically cement, to improve the excess water discharge system in the raffinate feed holding tank or by adding a raffinate dewatering system to ensure a consistent moisture content and a drier raffinate sludge feed.

Failure of the treated material to pass the TCLP criteria may not be so easily addressed. Feed streams may be combined to allow formulation of an acceptable product, but modification of the reagent mixture or additive ratio may be necessary. Supplemental reagents to aid in the attenuation of the compounds failing the TCLP criteria could be examined. For example, ferrous sulfate could be added to the grout to adsorb and/or precipitate arsenic as a relatively insoluble ferroarsenate compound. Alternatively, sodium sulfide could be added to precipitate arsenic as an insoluble arsenosulfide compound. Numerous reagents are known to attenuate specific contaminates during CSS processing and may be required if the treated product using the base-case reagent blend fails to pass the TCLP criteria.

Disposal of the CSS product and minimally treated wastes into a combination cell is considered a reliable process. Although placement tests have not performed, it is likely that the CSS wastes can be easily placed and effectively compacted. The CSS grout-like material will assist in the immobilization of building debris that is placed in the cell. Placement of the grout in and around voids in the debris will negate the need for hand-digging and placement of material around the building debris to prevent settlement. The building debris may also act to strengthen the grout monolith much as rebar does in concrete. The presence of the strong grout will assist in preventing cell cover failure caused by settlement of the wastes. The presence of CSS product should not adversely impact the performance of the leachate collection and removal system.

The reliability of land-based disposal facilities is difficult to assess because historical performance has been poor. Only recently, however, have systems utilizing double containment been employed. One mechanism to monitor the performance of these systems is to measure flows of liquids into the leakage detection layers. Bonaparte and Gross in "Field Behavior of Double-Liner Systems" (1990) present a case study with data from 55 individually monitored landfill cells. When EPA promulgated the minimum technology requirements of the 1984 Hazardous and Solid Waste Amendments (HSWA) and the associated Liner/Leak Detection System Rule of May 20, 1987, an action leakage rate of 5 gallons to 20 gallons/acre/day (gpad) was proposed as a threshold flow rate. The data presented by Bonaparte and Gross indicate that, of the 55 cells, 23 were constructed with geomembrane top liners (instead of composite top liners). Eleven of those 23 cells were constructed using EPA construction quality assurance (QA) procedures and were operating so that other potentials sources of flow, such as construction water, were minimized. Focusing on the 11 cells which would be most representative of the double-lined cell proposed for the CSS alternative, 4 had flow rates less than 5 gpad, 4 had flow rates between 5 gpad and 20 gpad, 3 had flow rates between 20 gpad and 50 gpad, and none had flow rates above 50 gpad.

In summary, it appears that 73% of the cells (8 out of 11) had an LCRS flow rate of less than 20, which compares very favorably to the original flow rates anticipated by EPA in establishing the performance standards for these systems.

The Liner/Leak Detection System Rule promulgated by EPA in 1987 has since been finalized (January 29, 1992). Subsequent studies will need to comply with the requirements of the finalized regulation.

7.4.3 Alternatives 7A, 7B, and 7C - Removal, Vitrification, and On-site or Off-site Disposal

As discussed previously, the vitrification process can be divided into three components: the grinding circuit; the melter system; and the off-gas treatment system. The following discussion focuses on the reliability of each of these systems, the types of likely technological failures, and the consequences of these failures.

7.4.3.1 Pretreatment Circuit. The components of the pretreatment circuit utilize well established and proven sizing reduction components and are considered very reliable. It is unlikely that pretreatment circuit-related problems will lead to schedule delays or to any technical failures. The most likely problem to occur would be a need to recycle material back to the pretreatment circuit for additional size reduction.

7.4.3.2 Melter System. The Vortec melter, which has been the focus of this study, has been modified from the melters used in the commercial glass manufacturing industry. These melters often achieve a 90% continuous operation efficiency. The Vortec system has not used in full-scale operation, and some scale-up and operational problems could be expected. These problems could be manifested as temperature control-related problems, incomplete melting, immiscible phase development, and thermocouple and heat sensor failure. These problems do not constitute a comprehensive list of all possible failures, but they do provide a measure of the types of problems that could develop. These are the sort of problems that could be rectified during both pilot-scale and in the initial phases of full-scale processing.

Refractory life is not expected to be a major concern because the Vortec system uses a cyclonic feeding method which helps protect the refractory surface from the melt and corrosive gases by a "wall" of unmelted feed material. Additionally the design life of the refractory is longer than the proposed plant operations.

Some temperature control problems could initially develop as the operators develop a feel for the effects of fuel addition changes prior to the calibration of computer-assisted controls. Temperature variation and improper control could result in the incomplete melting of feed materials. Actual processing of the waste materials may also show that different (higher) temperatures are required for complete melting. During temperature fluctuations and adjustments, it is possible that some phase immiscibility could develop. Immiscible phases would include the iron and sulfur phases described earlier.

Thermocouples seem to be prone to failure, which may necessitate using multiple thermocouples at critical locations to ensure that one is always operating or limiting the thermocouples to areas that are conducive to longer life. Thermocouple replacement and repair will likely be an important maintenance item.

The first glass produced by the Vortec system will probably contain partially unmelted material with immiscible phases. This glass should be recycled to the plant until a suitable, thoroughly melted product which is free from immiscible phases is generated. As discussed above, these are the types of items that should be addressed during pilot testing and initial full-scale production. The consequences of failure are minor since the initial improperly melted material can be easily handled and recycled.

7.4.3.3 Off-Gas Treatment System. Unlike the other components of the vitrification system which are conceptually established, the off-gas treatment system is less well defined. Although information on the reliability of joule-heated ceramic melter off-gas treatment systems is available, enough significant differences exist between the two technologies to cast doubt on extrapolating from JHCM off-gas treatment systems to FFHCM off-gas treatment trains. Since no field scale FFHCM systems have been deployed, there is no data upon which to base predictions regarding the reliability of the off-gas treatment train. Although this information will be obtained during future testing, adequate information does not presently exist, making the off-gas emissions of the FFHCM system one of the critical questions pertaining to its use. Numerous problems could develop in the off-gas treatment system during start-up. These problems could be related to the capabilities of an individual component, the production of excessive amounts of particulates that require secondary handling, the treatment of the scrub solutions prior to disposal, monitoring device calibration and maintenance, and problems that are exacerbated in one component from the effects of an upstream component. Although these problems can be resolved during future testing and optimization-required shutdowns of the facility, gas emissions exceeding regulatory criteria could lead to significant projects delays.

Failure of monitoring devices or marginal trial burn results could cause delays in startup or temporary suspension of activity until improved performance could be predicted.

Construction and disposal of vitrified and untreated material into the appropriate cell should be readily accomplished. Disposal cells incorporating radiation emission control characteristics, as for UMTRA cells, have been approved and constructed at several sites around the country. The UMTRA cells are new enough, however, to not have generated an extensive performance database. The overall simplicity of this type of design suggests that cell construction should not pose a significant problem.

Optimal placement methods for vitrified material into the cell have not been defined. Mixing of vitrified glass and clay material, followed by placement and compaction, is thought to yield an adequately compacted media. Alternatively, placement of soil and glass into separate, thin lifts may be adequate for cell cover support. The use of grout may be necessary to prevent settlement around building debris and to obviate the need for hand-digging and placement around building debris. This grout could be prepared specifically for this purpose with uncontaminated or minimally contaminated soil, or CSS-treated vitrification off-gas solutions could be used to stabilize the building debris. Placement of an adequately compacted material, combined with the grouting of building debris, should support the cell cover and prevent premature cover failure due to waste settlement.

7.5 Ease of Undertaking Additional Remedial Actions

This section addresses the ease of and the likelihood of having to undertake additional remedial actions. This criterion largely measures the difference between on-site and off-site disposal, and not the difference between CSS and vitrification technologies. Additional remedial treatment of either the CSS or vitrified product is unlikely to be necessary. The implications of the loss of access to the area upon which an on-site cell is located, the cell's initial capacity, and the need to dismantle the vitrification plant prior to cell closure have been considered and are discussed below.

7.5.1 Alternative 1 – No Further Action

The no further action alternative will not interfere with additional remedial actions.

7.5.2 Alternative 6A - Removal, Chemical Stabilization, and On-Site Disposal

It is unlikely that further remediation will be required for the CSS treated waste. However, CSS treatment is not irreversible, and the CSS product could conceivably be hydrometallurgically processed or vitrified. Disposal of material in an on-site cell could potentially impact the ability to perform additional remedial actions. An on-site cell might impact groundwater remediation by eliminating the location of groundwater removal or injection wells or monitor wells within the cell footprint. However, remediation of contaminated groundwater on-site may be implausible regardless of the existence of an on-site disposal cell. Unforeseen quantities of waste exceeding the cell design capacity could also be an operational problem associated with on-site disposal. After cell closure, additional waste placement in the cell would be very difficult. Moreover, treatment capability would be lost as the treatment facility would be dismantled and placed within the cell. Consequently, newly discovered contaminated material or a change in the removal or treatment action level would present a problem.

7.5.3 Alternatives 7A, 7B and 7C - Removal, Vitrification, and On-site or Off-site Disposal

It is unlikely that further remedial action will be required for the vitrified product; in fact, virtually no other treatment is possible. The difficulties undertaking additional remedial actions under an on-site disposal option are discussed in Section 7.5.2 above. With the off-site disposal option, the vitrification facility could be placed on stand-by without interfering with cell closure and be available to process newly discovered contaminated material.

7.6 Ability to Monitor Effectiveness of Remedy

This section focuses on the ability to monitor the effectiveness of the remedy and to identify potential risk sources and determine if associated exposure pathways exist. The CSS alternative has two potential exposure pathways: leachate derived from the CSS product and untreated material and radon emissions. It is likely that CSS treatment will not strongly impede radon diffusion from the waste. The vitrification alternative has two potential exposure pathways: leachate derived from the glass and untreated material and off-gas emissions. Previous studies have shown that radon should not diffuse at a sufficient rate from glass to constitute a concern. Dust derived from excavation activities are common to both the CSS and vitrification alternatives. The following discussion addresses these potential exposure pathways.

7.6.1 Alternative 1 – No Further Action

No additional technology will be used except for environmental monitoring and operation and maintenance of existing facilities. These are common activities which are routinely performed. The design life of the MSA, TSA, and water treatment plants is 10 years. These facilities will probably continue to function for a period of time after 10 years, but maintenance of these facilities will become more difficult and they will eventually fail.

Without maintenance, the raffinate pit dikes and any remaining buildings will eventually fail, and site contaminants will be released to the surrounding environments.

7.6.2 Alternative 6A – Removal, Chemical Stabilization, and On-site Disposal

Continual testing of the CSS product will be performed to ensure that criteria are met for TCLP testing and unconfined compressive strength of 50 psi. Passage of these tests will document production of a grout or cement soil that will adequately immobilize contaminants and support the disposal cell cover. Should a scheduled sample fail either the TCLP or compressive strength test, an immediate analysis will be performed to determine potential causes and mitigative measures to be taken. If a subsequent daily sample fails either criteria, the operation will be suspended until modifications to reestablish compliance are defined. Various mitigative techniques may include modification of the reagent blend or additive ratio, excess water elimination, or the use of contaminant-specific attenuating compounds. Treated material represented by the failed sample that has already been placed within the cell will not be reclaimed.

Leachate emanating from the emplaced waste will be captured by the dual leachate collection and removal systems within the engineered cell. The collected leachate will be directed to sumps and ultimately to the water treatment facility. Within a few years after disposal, leachate drainage will cease because all drainable free water will be removed from the waste and infiltration of surface water into the cell will be prevented by the cover system.

Activities associated with the monitoring of the cell during construction and subsequent closure will include periodic visual inspection of the cell cover to identify and repair areas of erosion, animal burrows, or tree roots. Survey monuments will be placed on the cell to allow settlement measurements to be obtained. Testing of the radon barrier will be performed within one year of placement to ensure that radon flux is less than 20 pCi of Rn-222 per square meter per second. Radon collecting carbon devices or other appropriate instrumentation will be used to measure radon emission from the cell during this test. Further studies will evaluate the potential for leachate leakage from the cell and assess the ability and the need for vadose zone monitoring below the cell. These studies will help determine specific locations for groundwater monitor wells to ensure timely detection of escaping leachate. Leachate generation should reach a maximum shortly after cell closure with a subsequent decrease to a steady state condition gradually decreasing to a minimal output. A significant increase in leachate generation after a period of consistent output would suggest that rain or snowmelt is infiltrating the cover system and would instigate a thorough cell cover inspection and repair program. The various cell monitoring components will form a systematic network to aid in the prevention of undetected migration of contaminants to a potential receptor.

7.6.3 Alternatives 7A, 7B and 7C - Removal, Vitrification, and On-site or Off-site Disposal

Production of a relatively unleachable glass adequately immobilizes contaminants for thousands of years. Literature information does not reveal a glass product failing TCLP or similar leach criteria testing. Consequently, migration of contaminants is largely prevented. To ensure contaminants are attenuated, continual TCLP testing will performed. This continual TCLP testing will likely document that virtually no leached contaminants are detected and that the product greatly exceeds regulatory criteria. In the event that a weekly sample does fail the TCLP criteria, daily samples will be collected, tested, and analyzed to determine the reason for failure. If two consecutive samples fail the TCLP tests, activities will cease until the cause is identified and preventive measures implemented. Failed material will not be reclaimed for retreatment.

Emissions during processing will be limited to the off-gas treatment system. The pretreatment and melter circuits are sealed and filter equipped systems will prevent dust emissions.

The off-gas will be processed through the treatment system described in Section 4.3.5.6.5. The following table presents conservative mass balance estimates of contaminant concentrations in the off-gas after treatment for maximum short-term and annual average emission rates.

TABLE 7-7 Mass Balance Estimates of Off-Gas Contaminant Concentrations

Contaminants of Concern	Controlled Emission Rate (g/s) Maximum Short-Term (1.24-hour)	Annual Average
Solids (PM-10)	0.000063	0.000039
Metals/Metalloids		
Lead	0.000071	0.000012
Arsenic	0.000305	0.000052
Cadmium	0.000108	0.000003
Selenium	0.000081	0.000016
Mercury	0.031	0.0038
Anions/Acid-Gases		
NO_x from feed (as NO_2)	24.6	2.2
SO_2	1.015	0.25
HCl	0.005	0.00056
HF	0.034	0.0035
Nitroaromatics		
2,4,6 TNT	0.000336	0.000017
2,4 DNT	0.000007	0.000001
2,6 DNT	0.000014	0.000001
Radionuclides (Ci/year)		
U-234	2.0×10^{-8}	2.2×10^{-19}
U-238	2.8×10^{-8}	2.6×10^{-19}
Th-230	9.2×10^{-7}	4.2×10^{-18}
Th-232	1.0×10^{-8}	4.9×10^{-20}
Ra-226	2.1×10^{-7}	2.2×10^{-18}
Ra-228	1.5×10^{-7}	5.2×10^{-19}
Pb-210	8.5×10^{-3}	1.3×10^{-13}
Po-210	3.6×10^{-7}	5.1×10^{-18}
Rn-222	213	24
Combustion Gases		
CO0.46	0.28	
NO_x as NO_2 (combustion)	15.8	9.6
Total NO_x (feed + combustion)	40	11.8

The composition of the vitrification off-gas (uncontrolled) is estimated to be the following ("wet" gas basis):

CO_2	9%	
N_2	71%	
H_2O	18%	
O_2	2%	(from 10% excess air feed)

The approximate concentrations of other products included in the off-gas are listed below.

SO_2	300	ppmv
CO	100	ppmv
NO_x	250	ppmv
Metals (Pb, As, Cd, Se, Hg)	100	ppmv
Radon	0.024	Ci/hr (maximum rate)

The off-gas treatment system will be equipped with real-time detectors to monitor the off-gas composition. Recycling of off-gas can be performed if off-gas composition exceeds performance criteria. If operational changes do not cause the off-gas to fall within the regulatory limits, the system will be shut down until corrections are made in the system or feedstock. A detailed discussion of the off-gas treatment system is provided in Section 3. Upon final conceptualization of the off-gas treatment system the optimal monitoring devices will be identified and positioned within the treatment train.

8 TIME TO IMPLEMENT

The overall time required to implement a specific alternative depends on construction sequencing and the operational production rates that can be achieved. The overall time to implement could be prolonged if sequential activities are delayed because preceding activities have not been completed on schedule. Production rates are affected by the selected crew sizes used in completing the activity, as well as the level of personal protection gear used by the crews.

Many of the components within each remedial action alternative are common to all. Table 8-1 lists the durations for activities common to Alternatives 6A, 7A, 7B, and 7C. Table 8-2 is a summary of mandays required to complete each of the five alternatives. The following sections discuss each alternative individually, including the no-action alternative. Section 8.4 contains an overall time to implement summary for all alternatives.

TABLE 8-1 Time to Implement Remedial Actions Common to All Alternatives
(Approximate Duration - Months)

Activity	Engineering	Bid/Award	Construction	Operation
Remediate Raffinate Pits	6	4	61	--
Site Preparation	4	3	16	--
Building Foundation & U/G Pipe Removal	4	3	31	--
Soil and Sediment Excavation	3	4	--	70
Material Hauling	4	3	--	54
Decontamination Station	2	3	4	88
Material Staging Area	4	3	12	54
Volume Reduction Facility	3	3	6	52
Water Treatment Plant (Train 1 and 2)	6 *	3 *	12 *	88
Building 434 Waste Removal	3	4	--	88
Remove Facilities	4	4	6	--
Site Restoration	4	4	10	--
Vicinity Properties (Phase 1, 2 and 3)	6 *	2 *	3 *	--

* Each phase.

TABLE 8-2 Manday Summary

	Removal, On-Site Hauling & Reclamation	Size Reduction	Vitrification	Chemical Solidification/ Stabilization	Disposal Cell	Off-Site Transportation	Water Treatment	Total[a] Mandays
Alternative 1 No Further Action	0.0	0.0	0.0	0.0		0.0	7,232.5	7,232.5
Alternative 6A CSS On-Site Disposal	52,707.3	4,449.5	0.0	10,660.0	42,600.0	0.0	7,232.5	117,649.3
Alternative 7A Vitrification On-Site Disposal	52,707.3	4,449.5	61,632.0	0.0	51,250.0	0.0	7,232.5	177,271.3
Alternative 7B Vitrification Off-Site Disposal at Clive, Utah	52,707.3	5,258.5	61,532.0	0.0	51,250.0	72,702.0	7,232.5	250,782.3
Alternative 7C Vitrification Off-Site Disposal at Hanford, Washington	52,707.3	5,258.5	61,632.0	0.0	51,250.0	72,702.0	7,232.5	250,782.3

[a] Based on 6.5 effective hours per day.

8.1 Alternative 1 - No Further Action

As described in Section 2, the no further action alternative consists of these basic elements:

- The quarry bulk waste is in storage at the temporary storage area.
- The chemical plant buildings have been dismantled and are in storage at the material staging area.
- The raffinate pit sludges, chemical plant contaminated soils and sediment, and the vicinity properties contaminated soils and sediments remain in place.
- The site water treatment plant is operational.
- Miscellaneous waste stored in Building 434.

- Rubble and soil waste stored in Ash Pond spoil pile.

- Chipped wood stored in mulch pile.

The elements for the no-action alternative and the anticipated time periods are shown in Table 8-3.

TABLE 8-3 Time to Implement - No-Action Alternative
(Approximate Duration - Months)

Activity	Engineering	Bid/Award	Construction	Operation
Temporary Storage Area[a]	6	2	7	8
Material Staging Area[a]	2	3	12	5
Water Treatment Plant	6	3	12	88
Chemical Plant Building Dismantlement[a]	13	3	30	--
Site Preparation	4	3	16	--

a Performed as interim response action

8.2 Alternative 6A – Removal, Chemical Stabilization, and On-site Disposal

Alternative 6A is comprised of chemical solidification/stabilization treatment of selected wastes; all wastes will then be disposed in an on-site disposal facility.

8.2.1 CSS Facility and Treatment

More than 7.5 years will be required to complete all activities associated with processing 320,000 cubic yards (374,200 tons) of undewatered raffinate sludges, raffinate pit clay bottom, and quarry soils into 422,000 cubic yards (612,500 tons) of CSS product. The major steps required to execute the CSS treatment alternative and the number of work and calendar days anticipated to accomplish each step are listed in Table 8-4.

TABLE 8-4 CSS Process Milestones and Schedule

CSS Process Milestone	Work days	Since Start
1. Pilot Test of CSS	250	12 Months
2. Detailed Design of CSS Plant	250	24 Months
3. Requests for Bids and Award of Contracts	40	26 Months
4. Design, Fabrication, Installation, Testing	250	38 Months 3 Yrs. 2 Mos.
5. Operation with 10% Downtime, 9 Months/Year	795	91 Months 7 Yrs. 7 Mos.
Total 8-hour Work Days	1,584	

The CSS plant will operate, at a scheduled plant availability of 90%, over a 4.5-year period at 6.5 productive hours per day (out of an 8-hour work day), 20 work days per month, 9 months per year, allowing for a 3-month winter shutdown.

8.2.2 On-Site Disposal

Construction of the disposal facility will occur over a 78-month period. Material placement will need 57 months within the 78-month period. Facility design is estimated at 12 months; bid and award at 6 months.

8.3 Alternatives 7A, 7B and 7C – Removal, Vitrification, and Off-site or On-site Disposal

Alternative 4B is comprised of vitrification of selected wastes; all wastes will then be disposed in an on-site disposal facility. Alternative 7A differs from Alternatives 7B and 7C in that waste will be disposed in an off-site facility rather than an on-site facility.

8.3.1 Vitrification Facility and Treatment

Nearly 8 years will be required to complete all activities associated with processing 320,000 cubic yards (374,000 tons) of raffinate sludge, raffinate pit clay bottom, and quarry soils into 102,000 cubic yards (181,540 tons) of fritted glass. The vitrification rate will be 125 tons of material per 24-hour day, 365 days per year at a scheduled availability of 90%. At this rate, the selected waste will be processed in approximately 4 years. The major steps required to carry out waste vitrification and the number of work days required to accomplish each step are listed in Table 8-5.

TABLE 8-5 Vitrification Process Milestones and Schedule

FFHCM Process Milestone	Work Days	Since Start
1. Bench and Pilot Test of FFHCM 8 hours/day, 20 work-days/month	480	24 Months
2. Complete Detailed Design of the FFHCM Treatment Unit	125	30 Months
3. Requests for Bids and Award of Contracts	40	32 Months
4. Design, Fabrication, Installation, Testing	313	47 Months
5. Operation with 90% Availability, 24 hours/day, 365 days/year	1,460	95 Months 7 yr - 11 months
Total Work Days	2,418	

8.3.2 Off-Site Disposal

As described in Section 4, two potential off-site facilities have been identified in the FS (DOE 1992a) for waste disposal: Clive, Utah (Alternative 7B) and Richland, Washington (Alternative 7C). Assuming both sites have completed all permitting, the time to implement will be the same. The time to implement off-site disposal includes:

Transport procurement	12 months
Material transport and disposal	60 months

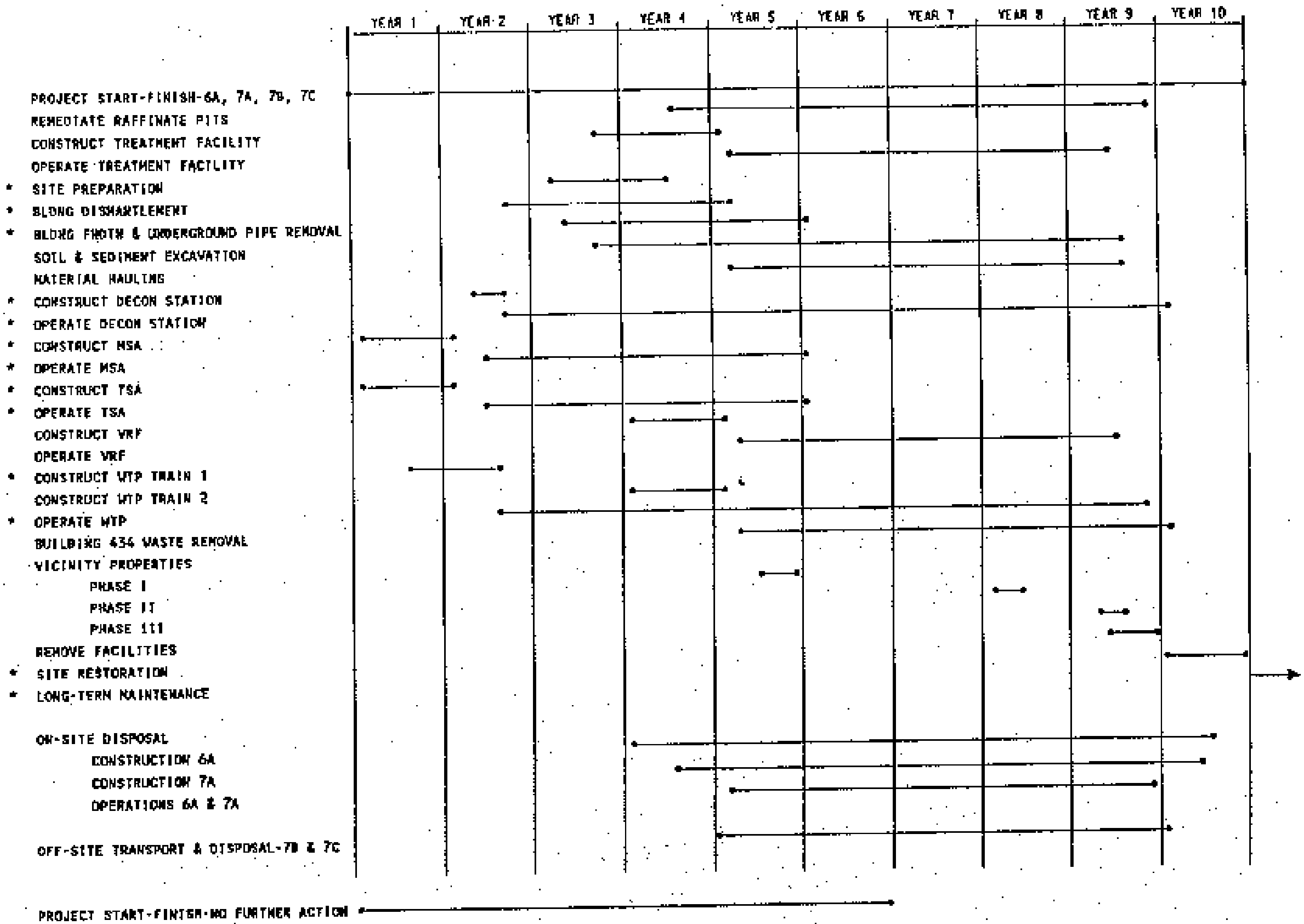
8.3.3 On-Site Disposal

Construction of the disposal facilities will occur over a 72-month period. Material placement will need 57 months within the 72-month facilities construction period. Facility design is estimated to require 12 months and bid and award to require 6 months.

8.4 Summary

Figure 8-1 shows the overall time to implement, excluding long-term maintenance, for each alternative under consideration. It is projected that alternatives 7A, 7B, and 7C will each require 10 years to implement.

FIGURE 8-1
Time to Implement



* ACTIVITIES IN NO FURTHER ACTION: DIFFERENCES IN SCHEDULE FROM 6A, 7A, 7B, 7C NOT SHOWN ON FIGURE.

9 COST ANALYSIS

This section presents estimated costs for the remedial action alternatives evaluated in this report. It should be noted that all costs presented throughout this document are preliminary in nature and are based on preconceptual-level designs. As more definitive characterization data and technology optimization studies become available, it is likely that design concepts and cost estimates will change from those presented here.

Table 9-1 presents the total project construction and operation cost summary, for each remedial action alternative considered by major activity category. The sections below discuss cost elements pertinent to each alternative. More detailed cost information is contained in Appendix A, *Alternatives Summary Cost Estimate.*

TABLE 9-1 Remedial Action Alternative Total Project Cost Summary ($1,000s)

Activity	No Further Action	On-site Disposal		Off-site Disposal	
		Chemical (6A)	*Vitrification (7A)	Clive (7B)	Richland (7C)
Remediate Raffinate Pits	--	11,900	14,400	14,400	14,400
Bench- and Pilot-Scale Testing	--	2,100	8,200	8,200	8,200
Construct Treatment Facility	--	3,100	25,600	25,600	25,600
Operate Treatment Facility	--	14,700	20,500	20,500	20,500
Chemical Plant Site Preparation	--	2,800	2,800	2,800	2,800
Building Foundation and Underground Pipe Removal	--	6,000	6,000	6,000	6,000
Soil and Sediment Excavation	--	1,700	1,700	1,400	1,400
Material Hauling	--	9,700	9,300	33,200	33,200
Disposal Cell Operations	--	7,200	6,700	--	--
Construct Decontamination Station	50	50	50	50	50
Construct VRF	--	2,900	2,900	2,900	2,900
Construct WTP Train 2	--	1,200	1,200	1,200	1,200
Building 434 Waste Removal	--	600	600	600	600
Operate TSA	2,000	2,000	2,000	2,000	2,000
Operate MSA	5,200	5,200	5,200	5,200	5,200
Operate Decontamination Station	600	1,200	1,200	1,200	1,200
Operate VRF	--	2,500	2,500	2,500	2,500
Operate WTP	2,000	3,500	3,500	3,100	3,100
Disposal Facility Construction Material Tests	--	900	900	--	--
Construct Disposal Facility					
CSS Scenario	--	47,600	--	--	--
Vitrification Scenario	--	--	37,100	--	--
Remove Facilities	--	1,800	1,800	1,800	1,800
Site Restoration	--	3,400	3,400	3,200	3,200
Vicinity Properties					
Phase 1 (Army 1, 2, 3 and Busch 3, 4, 5)	--	400	400	400	400
Phase 2 (Lakes 34, 35, 36)	--	400	400	400	400

Phase 3 (Army 5 and 6)	--	300	300	300	300
Off-Site Transport and Disposal	--	--	--	214,400	142,919
Long-Term Maintenance	15,900	23,900	23,900	--	--
Total (rounded)	26,750	157,050	182,550	351,350	279,869
Present Worth (rounded)	10,000	79,600	97,800	197,500	157,319

9.1 Alternative 1 - No Further Action

The activities contained in the no further action alternative are also part of the other remedial action alternatives, although, in some cases, not at the same level of effort. As shown in Table 9-1, the no further action alternative does not equate to no expense incurred. The estimated total cost for the no further action alternative is $28,450,000.

9.2 Alternative 6A - Removal, Chemical Stabilization, and On-site Disposal

Estimated capital costs for the major equipment components of the CSS treatment facility are listed in the following table. Vendor quotes were obtained for this equipment.

Description	Total Cost ($)
Slurry/Mixer Tank (25 HP)	65,000
12,650 ft³ Cement Silo	77,500
15,000 ft³ Fly ash Silos	265,000
20 CFM/150 psi Air Compressor (1.5 HP)	3,500
115-foot Horizontal Screw Conveyor (30 HP)	25,000
60-foot 25° Screw Conveyor (30 HP)	20,000
Mixer/Product Tank (75 HP)	75,000
Sludge/Slurry Pump (75 HP)	85,000
Pug Mill (100 HP)	40,000
Apron Feeder (15 HP)	7,500
Volumetric Feeder (1.5 HP)	17,500
Vibrating Screen (5 HP)	12,000
Live Bottom Bin (50 HP)	35,000
Truck Dump	15,000
Building (60 feet x 40 feet)	108,000
CAT 966E Front-End Loader	178,000
TOTAL	1,029,000

The estimated installed cost of the above equipment is $3,100,000. The cost estimates listed above are unlikely to significantly change since they were obtained through vendor quotes and the equipment needed is standard and can be readily obtained. With bench-scale and pilot-scale testing costs of $2,100,000, the total plant cost is an estimated $5,200,000.

Total operating costs are estimated at $14,700,000 for processing approximately 324,000 bank cubic yards of wastes. Total treatment costs are estimated at $62 per cubic yard.

The cost to construct the single-cell disposal facility is $47,600,000. The cell configuration is double liners over a clay-compacted bottom.

9.3 Alternatives 7A, 7B and 7C – Removal, Vitrification, and On-site or Off-site Disposal

The following equipment is required for vitrification treatment.

Raffinate sludge pretreatment equipment	$ 682,500
Soil and clay pretreatment equipment	1,144,000
Feed blending equipment	179,000
Vitrification/product handling equipment	2,718,000
Buildings	1,574,000
Off-gas system	716,200
Total	$ 7,013,700

The estimated installed cost of the above equipment is $25,600,000, including the gas feed line. The above costs could change by selecting vendors other than those used for obtaining these equipment quotes, by using different styles of equipment than those quoted (e.g., plasma arc torch melters instead of Vortec's fossil fuel-heated ceramic melter), and by changing the treatment design throughput so that installation and operation of more and/or larger vitrification treatment units are required. With $1,700,000 estimated for dewatering equipment and $8,200,000 for bench- and pilot-scale testing, the total plant cost is an estimated $35,500,000.

Total operating costs including dewatering are estimated at $21,300,000 for processing 324,000 bank cubic yards of waste. Total cost to treat is estimated at $176 per cubic yard.

The cost to construct the two-cell disposal facility is $37,100,000. Recall that one cell is singly-lined over a clay-compacted bottom. The other cell consists only of a clay compacted bottom.

Disposal fee quotes were obtained from Envirocare at Clive, Utah and the DOE Hanford facility near Richland, Washington. Rail transport price quotes were obtained from Union Pacific Railroad. Construction of a railroad siding at Wentzville is involved with rail transport options. Siding construction costs will be approximately $2,285,000.

The Envirocare disposal fee is \$144 per ton. The rail transport fee, which includes return of empty containers, is \$54 per ton. The total cost for off-site transport and disposal at the Clive, Utah, facility, including ancillary facilities, is \$214,400,000 for 1,082,600 tons of waste.

The Hanford disposal fee is \$100 per cubic yard. This quoted fee is for disposal of the Weldon Spring wastes at an existing facility at the Hanford site. However, this figure does not include closure or long-term monitoring costs and is very preliminary in nature. Earlier disposal costs at Hanford had ranged as high as \$1,944/cubic yard. A detailed cost analysis would be performed if disposal at Hanford were a component of the selected alternative. The rail transport fee, which includes return of empty containers, is \$69 per ton. The total cost for off-site transport and disposal at the Hanford, Washington, site, including ancillary facilities, is \$142,919,400 for 682,200 cubic yards (1,082,600 tons) of waste.

For purposes of this engineering evaluation, it was assumed that the K25 Incinerator at Oak Ridge would be available for treatment of the liquid wastes. The distance to Oak Ridge is approximately 500 miles. Transportation costs are estimated to be \$1.65 per mile, with an additional \$75 fee for loading or unloading times exceeding one hour. Based upon an 8-hour unloading time, a cost of \$68 per ton has been used to estimate the transportation charges. Incineration costs have not been identified because waste characterization is not complete. An incineration cost of 50 cents per pound has been used, based upon engineering calculations developed by the project.

9.4 Other Costs

Certain metals may be decontaminated by conventional methods in association with volume reduction. This engineering evaluation assumes that metals decontamination will be an integral part of the VRF or will be supported directly by VRF operations. However, if a VRF is not constructed, sizing and decontamination activities may be performed within certain storage areas as required. Decontamination of metals has not been included within the alternatives being considered. Cost estimates were developed for these technologies are listed in Table 9-2. These technologies are described in Section 4.2.4.

9.5 Summary

The following is a summary of the various remedial alternative cost elements, ranging from the most costly to the least expensive.

- **Off-Site Rail Transport and Disposal.** Disposal and rail transport fees cause this activity to be the most costly. Costs could rise because of increases in rates charged by the disposal facility and railroad. More attractive rates may possibly be negotiated because of the large quantity of material involved (approximately 700,000 yd^3/ 1,100,000 tons).

- **On-Site Disposal Facility.** The high disposal facility cost is a result of the facility construction production rates and material costs used to prepare the estimate. Vendor quotes were received for material prices, and conservative production rates were used. Costs could increase if subsequent investigations indicate that a larger disposal facility will be required than the facility upon which the estimate was based. Alternately, a cost decrease would result if higher production rates are achieved or material costs are lower than what is presumed.

  The vitrification treatment with on-site disposal alternative costs will increase if more stringent liner systems are determined to be necessary. The CSS treatment on-site disposal alternative costs will decrease if more lenient liner systems are determined to be adequate.

- **Off-Site Disposal Material Hauling.** Off-site disposal material hauling costs are high because of container costs, the need to construct a railroad siding at Wentzville, Missouri, and the transport costs for moving the waste from the site to the Wentzville siding. The overall cost will either increase or decrease, depending on the actual costs associated with container procurement and railroad siding construction. Costs could increase if documentation expenses for hazardous waste transport exceed the 8.8% of direct labor cost allowance for operating expenses.

- **Treatment Facility Construction and Operation.** Operating costs will primarily be affected by material and energy requirements. Vitrification treatment costs will increase should more energy be required or be more costly than what was presumed. Chemical treatment operating costs are mostly affected by cement and fly ash quantity requirements and the associated material prices.

- **Support Facilities Including Site Preparation and Restoration.** Support facilities include the material staging area, the volume reduction facility, the water treatment plant, and the decontamination area. Costs would be affected if the facilities in subsequent design work differ appreciably from those used in the current preconceptual design.

- **Long-Term Maintenance.** Long-term maintenance costs appear high because the total expenditure is distributed over a 30-year period. The most expensive item is annual environmental monitoring; cost is affected by the type of testing required and the frequency at which testing is performed. Another potential high cost item is major repairs to the on-site disposal facility, although stringent quality control procedures during facility design and construction should mitigate the need for costly repairs.

- **Building 434 Waste Removal.** Waste removal costs will be affected by the material quantity requiring disposal, the container costs for transport to the disposal facility, and the disposal fee charged by the facility. Documentation requirements could also cause the 8.8% operating expense provision to be exceeded.

- **Soil and Sediment Excavation/Material Hauling.** These costs are predominately affected by the material quantities and production rates used in estimating costs. Higher material quantities and slower production rates will increase costs.

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11 LIST OF ACRONYMS AND ABBREVIATIONS

Following is a list of the acronyms, initialisms, and abbreviations used in this document:

-A-

ACM	Asbestos-containing material
ALARA	As low as reasonably achievable
ANL	Argonne National Laboratory
ARAR	Applicable or Relevant and Appropriate Requirement
ASTM	American Society for Testing and Materials

-B-

BCY	Bank Cubic Yards
BDAT	Best Demostrated Available Technology
Btu	British Thermal Unit

-C-

°C	Degrees Celcius
Cat	Caterpillar
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulations
Ci	Curie(s)
cm	Centimeter
CMS	Combustion/melting system
CRV	Counter rotating-vortex
CSR	(Missouri) Code of State Regulations
CSS	Chemical solidification/stabilization
CWA	Clean Water Act

-D-

DF	Decontamination factor
DNR	(Missouri) Department of Natural Resources
DNT	Dinitrotoluene
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DRE	Destruction and Removal Efficiency
dscf	Dry Standard Cubic Foot

-E-

EAA	Engineering Analysis of Alternatives
Eh	Chemical Redox Potential
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
EP-TOX	Extraction Procedure Toxicity Test
EVS	Ejector-venturi scrubber

-F-

°F	Degrees Farenheit
FAA	Federal Aviation Administration
FCY	Fill Cubic Yard
FFHCM	Fossil Fuel-Heated Ceramic Melter
FHA	Federal Highway Administration
FOB	Freight on board
FML	Flexible membrane liner
FRSA	Federal Railway Safety Act
FS	Feasibility Study
ft^2	Square foot
ft^3	Cubic foot

-G-

g	Gram(s)
gal	Gallon(s)
gpm	Gallons Per Minute

-H-

H	Horizontal
HDPE	High-density polyethylene
HEME	High-Efficiency Mist Eliminator
HEPA	High-Efficiency Particulate Air
HLLW	High-level liquid waste
HMTA	Hazardous Materials Transportation Act
hp	Horsepower
hr	Hour(s)

-I-

IFR	Interim Final Rule
in	Inch(es)
IRA	Interim Response Action
ISV	In situ vitrification

-J-

JEG	Jacobs Engineering Group
JHCM	Joule-Heated Ceramic Melter

-K-

kg	Kilogram(s)
kw	Kilowatt(s)
kwh	Kilowatt hour(s)

-L-

l	Liter(s)
lb	Pound(s)
LCRS	Leachate Collection and Removal System
LDCRS	Leachate Detection, Collection, and Removal System
LLRW	Low-Level Radioactive Waste
LLW	Low-Level Waste

-M-

m	Meter(s)
m^2	Square meter(s)
m^3	Cubic meter(s)
M_b	Maximum body wave magnitude
MCC	Material Characterization Center
MDOC	Missouri Department of Conservation
mg	Milligram(s)
mi	Mile(s)
MKF	MK-Ferguson Company
MKE	Morrison-Knudsen Engineers
MKES	MK-Environmental Services Group
ml	Milliliter(s)
mm	Millimeter(s)
MOD 8	Modification M008 Proposal for Equitable Adjustment
mrem	Millirem(s)
MSA	Material Staging Area
μCi	Microcurie(s)
μg	Microgram(s)
μm	Micrometer(s)

-N-

NORM	Naturally Occurring Radioactive Material
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRC	Nuclear Regulatory Commission

-O-

OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response

-P-

PAH	Polyaromatic Hydrocarbons
PAT	Plasma Arc Torch
PCB	Polychlorinated Biphenyl
pCi	Picocurie(s)
PEC	Plasma Energy Corporation
pH	Negative log of hydrogen ion activity
PIC	Products of incomplete combustion
PNL	Battelle Pacific Northwest Laboratory
PPE	Personal protective equipment
ppm	Parts per million
ppmv	Parts per million by volume
psi	Pounds per square inch

-R-

RAD	Radiation Absorbed Dose
RCRA	Resource Conservation and Recovery Act of 1978
RI	Remedial Investigation
ROD	Record of Decision
RSPA	(U.S. DOT) Research and Special Programs Administration

-S-

SBS	Submerged-bed scrubber
sec	Second(s)
SOU	Source Operable Unit
SSM	Shallow soil mixing

-T-

TCLP	Toxicity Characteristics Leaching Procedure
TNT	Trinitrotoluene
TSA	Temporary Storage Area
TSCA	Toxic Substances Control Act

-U-

UCS	Unconfined Compressive Strength
UMTRCA	Uranium Mill Tailings Radiation Control Act of 1978
UMTRA	Uranium Mill Tailings Remedial Action (Project)

-V-

V	Vertical
VRF	Volume reduction facility

-W-

W/C	Waste to cement
WSSRAP	Weldon Spring Site Remedial Action Project
WSS	Weldon Spring Site
wt.	Weight
wt. %	Weight percent
WTP	Water treatment plant

-Y-

yd	Yard(s)
yd^2	Square yard(s)
yd^3	Cubic yard(s)

12 SYMBOLS OF ELEMENTS AND CHEMICAL COMPOUNDS

Al	Aluminum
Ar	Argon
As	Arsenic
B	Boron
B_2O_3	Boric Oxide (Boric Anhydride)
C	Carbon
Ca	Calcium
CaO	Calcium Oxide
CaOH	Calcium Hydroxide
$CaSO_4$	Calcium Sulfate
Cd	Cadmium
Ce	Cerium
CO_2	Carbon Dioxide
CO_3	Carbonate
F	Fluorine
H	Hydrogen
HCl	Hydrochloric Acid
H_2O	Water
He	Helium
HF	Hydrogen Fluoride
Hg	Mercury
K	Potassium
N	Nitrogen
Na	Sodium
$Na_2B_4O_5(OH)_4 \cdot 8H_2O$	Borax
$NaCO_3$	Sodium Carbonate
Na_2O	Sodium Oxide
NO_X	Nitrogen Oxides
Ra	Radium
Rn	Radon
S	Sulfur
SO_2	Sulfur Dioxide
SO_X	Sulfur Oxides
Si	Silicon
SiF_4	Silicon Fluoride (Tetrafluorosilane)
Th	Thorium

APPENDIX A
ALTERNATIVES SUMMARY COST ESTIMATE

ALTERNATIVES SUMMARY COST ESTIMATE

ACTIVITY	START	FINISH	DIRECT TOTAL ($)	INDIRECT TOTAL ($)	TOTAL B,M,I* ($)	TOTAL PROJECT ($)
DISPOSAL CELL/CHEMICAL PLANT OSS						
Clear and Grub Light	1 MR 93	6 MA 93	178,727	43,562	52,060	274,350
Clear and Grub Heavy	7 MA 93	20 JN 93	161,021	42,946	47,769	251,736
Construct Retention Pond	1 MA 93	1 JN 93	45,292	11,382	13,273	69,947
Double HDPE Liner Pond	7 JN 93	15 JN 93	68,340	1,573	16,374	86,286
Water Control Dikes	1 FB 94	15 JN 94	835,213	62,114	210,154	1,107,481
Southeast Drainage Control	1 MR 94	15 JL 94	307,667	39,466	81,299	428,432
Haul Road Fill	1 AP 93	20 MA 93	235,004	61,495	69,440	365,939
Haul Road Base	21 MY 93	10 JN 93	186,472	10,424	46,113	243,009
Foundation Mobilization	15 MA 93	1 JL 93	74,280	0	17,396	91,676
Foundation Training	15 MA 93	19 NV 95	133,322	32,015	38,722	204,059
Foundation Demobilization	1 NV 95	1 JA 96	74,280	0	17,396	91,676
Remove Foundations (Phs 1,2,3)						
Phase 1	23 JN 93	8 OC 93				
Phase 2	23 NV 93	23 AP 94				
Phase 3	10 OC 95	19 NO 95				
Foundation Exc/Bckfil						
Phase 1 36%			110,300	24,767	31,633	166,700
Phase 2 50%			153,201	34,400	43,936	231,537
Phase 3 14%			42,893	9,631	12,301	64,825
Foundation Breakage						
Phase 1			348,574	77,654	99,823	526,051
Phase 2			484,131	107,853	138,643	730,626
Phase 3			135,557	30,199	38,820	204,575
Foundation Haul						
Phase 1			60,583	14,715	17,635	92,933
Phase 2			84,144	20,438	24,493	129,074
Phase 3			23,560	5,723	6,858	36,141
Remove Underground Pipe	23 JN 93	18 NV 95	1,470,297	373,701	431,884	2,275,882

* B,M,I = Bond, Margin, and Insurance

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ALTERNATIVES SUMMARY COST ESTIMATE (Continued)

ACTIVITY	START	FINISH	DIRECT TOTAL ($)	INDIRECT TOTAL ($)	TOTAL B,M,I* ($)	TOTAL PROJECT ($)
Backfill Pipe Trench			405,811	107,794	120,266	633,891
Remove Contaminated Material			165,381	42,855	48,769	257,005
Winter Shutdown - Chmcl Plnt	1 DC 93	1 MR 99	213,348	0	49,966	263,314
Contaminated Soil Excavation						
North Dump	1 JL 93	1 AG 93	67,100	16,273	19,526	102,899
Ash Pond	2 JN 99	6 JL 99	107,714	26,122	31,344	165,180
Frog Pond	11 AP 96	5 MY 96	68,866	16,701	20,040	105,607
Install Gravel Base						
Ash Pond	2 JN 99	6 JL 99	56,730	471	13,396	70,597
Frog Pond	11 AP 96	5 MY 96	11,346	94	2,679	14,119
Dewater Frog Pond	25 MR 96	10 AP 96	12,085	2,442	3,402	17,929
South Dump	15 OC 97	1 DC 97	149,210	36,186	43,420	228,815
Surface Soil						
Phase 1	7 OC 93	1 NV 93	89,390	14,090	24,236	127,716
Phase 2	1 MR 95	2 AP 95	150,176	23,671	40,715	214,562
Phase 3	1 MR 96	2 AP 96	150,176	23,671	40,715	214,562
Mobilization Soil Excavation	7 OC 93	6 JL 99	17,107	0	4,006	21,113
Training Soil Excavation	15 SP 93	6 JL 99	138,756	33,875	40,431	213,063
Demob Soil Excavation	2 NV 93	1 AG 99	17,107	0	4,006	21,113
Equipment Decontamination	2 NV 93	1 AG 99	89,855	29,545	27,963	147,363
Reclamation Backfill						
Phase 1	2 NV 93	9 DC 93	164,957	38,855	47,733	251,545
Phase 2	3 AP 95	3 JN 95	253,441	59,697	73,337	386,475
Phase 3	3 AP 96	10 MY 96	172,037	40,523	49,782	262,342
Fence Removal & Installation	15 SP 00	27 OC 00	94,500	0	11,529	106,029
	28 OC 00	20 DC 00	86,708	26,613	26,540	139,860
Reclamation Backfill	1 MR 00	15 AG 00	874,637	206,019	253,090	1,333,746
Topsoil	15 JN 00	15 SP 00	475,671	49,627	123,025	648,322

* B,M,I = Bond, Margin, and Insurance

ALTERNATIVES SUMMARY COST ESTIMATE (Continued)

ACTIVITY	START	FINISH	DIRECT TOTAL ($)	INDIRECT TOTAL ($)	TOTAL B,M,I* ($)	TOTAL PROJECT ($)
Seed and Mulch	20 JL 00	1 SP 00	68,502	9,603	18,292	96,397
Site Restoration Mob	1 FB 00	15 JN 00	28,524	0	6,680	35,204
Site Restoration Train	1 FB 00	1 SP 00	38,272	9,227	11,124	58,623
Site Restoration Demob	16 AG 00	15 SP 00	28,524	0	6,680	35,204
OPERATIONS						
MSA Construction	18 FB 91	18 FB 92				0
Operate MSA	19 JN 91	19 JA 96	3,284,600	869,475	979,910	5,163,986
Operate TSA	15 JL 93	15 JL 95				2,002,194
Construct Decon Pad	1 MA 92	15 AG 92	30,199	4,654	8,163	43,016
Operate Decon Facility	16 AG 92	1 JA 00	730,558	229,907	224,941	1,185,407
Construct WTP			4,841,088	134,156	1,165,202	
Train 1	11 OC 91	15 AG 92				0
Train 2	28 FB 94	28 FB 95				1,187,918
Operate WTP On Site	16 AG 92	11 NV 99	2,343,733	465,326	657,882	3,466,941
Construct VRF	28 FB 94	28 FB 95	2,266,282	31,003	538,024	2,835,309
Operate VRF	1 MR 95	1 JL 99	1,679,419	356,716	476,863	2,512,998
Building 434 Load	1 MR 95	1 JA 00				191,573
Building 434 Haul PPE Mtrls	1 MR 95	1 JA 00				377,180
Haul to Size Reduction	1 MR 95	1 JL 99	481,647	116,988	140,200	738,835
Transport Rubble	1 MR 95	1 JN 99	227,150	55,173	66,120	348,442
Haul Clay/Soil CSS Process	1 MR 95	1 JN 99	228,992	35,292	61,895	326,179
Haul Rubble to Cell	1 MR 95	1 AG 99	1,953,572	482,041	570,421	3,006,035
Transport Soils etc.	1 MR 95	1 AG 99	617,847	143,754	178,367	939,968
Haul Treated Waste to Cell New Estimate						
CSS Process	1 MR 95	1 JN 99	2,816,268	722,704	828,827	4,367,799
Remove Haul Roads	2 OC 99	2 DC 99	147,766	35,969	43,031	226,765
Remove Control Dikes	21 SP 99	10 NV 99	353,181	84,440	102,491	540,112
Remove TSA	2 AG 99	15 SP 99	174,641	38,076	49,818	262,536

* B,M,I = Bond, Margin, and Insurance

ALTERNATIVES SUMMARY COST ESTIMATE (Continued)

ACTIVITY	START	FINISH	DIRECT TOTAL ($)	INDIRECT TOTAL ($)	TOTAL B.M.I* ($)	TOTAL PROJECT ($)
Remove MSA	2 AG 99	20 SP 99	201,046	45,965	57,850	304,861
Remove Treatment Facility	2 JN 99	2 JL 99	105,633	28,029	31,304	164,965
Remove Water Treatment Facility	11 NV 99	2 DC 99	63,673	18,927	19,345	101,945
Remove VRF Facility	21 SP 99	22 OC 99	105,633	28,029	31,304	164,965
Cell Operations	1 MR 95	2 DC 99				
Place Soil/Rubble			3,091,781	859,293	925,341	4,876,415
Place CSS Waste			1,549,446	359,101	446,982	2,355,529
CELL CONSTRUCTION PHASE 1,2,3						
Fill Performance Tests	1 MR 92	1 JL 92	449,829	10,770	107,872	568,472
Borrow Source Evaluation			219,485	16,096	55,173	290,753
Liner Compatibility Tests			16,000	0	3,747	19,747
Mob/Demob			20,192	0	4,729	24,921
Foundation Phase 1	1 MR 94	1 DC 94				
Foundaton Phase 2	4 JN 95	1 JN 96				
Foundation Phase 3	1 MR 97	1 DC 97				
Prepare Cell Subgrade			21,156	5,710	6,292	33,158
Cell Subgrade Excavation/Fill			298,303	58,651	83,599	440,553
Place Cell Foundation Clay			2,930,793	636,529	835,467	4,402,789
Cell Foundation HDPE Liner			1,458,000	31,983	348,954	1,838,937
Cell Foundation Gravel			2,475,342	160,751	617,373	3,253,465
Cell Collection/Discharge Pipe			242,212	40,272	66,158	348,641
Cell Foundation HDPE Liner			1,458,000	31,983	348,954	1,838,937
Cell Foundation Gravel			2,475,342	160,751	617,373	3,253,465
Cell Foundation Sand			841,482	107,335	222,213	1,171,030
Cell Foundation Concrete Summ.			167,642	37,387	48,018	253,046
COVER						
Cover Phase 1	1 FB 95	17 DC 96				
Cover Phase 2	1 MY 98	1 JN 98				

* B.M.I = Bond, Margin, and Insurance

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ALTERNATIVES SUMMARY COST ESTIMATE (Continued)

ACTIVITY	START	FINISH	DIRECT TOTAL ($)	INDIRECT TOTAL ($)	TOTAL B,M,I* ($)	TOTAL PROJECT ($)
Cover Phase 3	1 MR 98	15 JL 00				
3 ft Frost Protection Layer Side			2,576,789	576,059	738,397	3,891,245
4 ft Clay Cover Side			3,531,606	767,018	1,006,738	5,305,361
4 ft Clay Cover Top			395,657	85,931	112,788	594,377
2 ft Frost Protection Cover Top			199,310	44,557	57,114	300,980
Install HDPE Side			1,351,744	38,497	325,594	1,715,835
Install HDPE Top			145,800	3,198	34,895	183,894
Filter Side			769,156	95,784	202,569	1,067,509
Rip Rap Side			1,379,621	157,259	359,937	1,896,816
Choke Rock Side			825,963	119,923	221,526	1,167,412
Filter Top			153,831	19,157	40,514	213,502
Choke Rock Top			192,725	27,982	51,689	272,396
Install Drain Top			179,470	22,350	47,266	249,085
Place Sod CSS	15 FB 00	15 JL 00	1,049,220	144,644	279,603	1,473,466
Haul Road Maintenance	10 JN 93	15 JL 00	250,957	50,520	70,606	372,083
Cell Dewatering	1 MR 94	1 MR 00	570,412	152,596	169,329	892,337
Clear Cover Borrow	1 OC 94	1 DC 94	87,500	0	10,675	98,175
Mobilization Cell	1 FB 94	1 JN 96	502,139	0	117,601	619,739
Training Cell	1 FB 94	1 JL 00	252,529	61,647	73,580	387,756
Winter Shutdown - Cell	1 DC 94	1 MR 00	2,195,865	0	514,272	2,710,137
Decontamination - Cell	1 JN 99	1 FB 00	294,071	96,693	91,517	482,280
Demobilization - Cell	1 JN 99	1 AG 00	502,139	0	117,601	619,739
Disposal Cell Engineering	1 MR 92	1 JA 94	1,297,791	0	303,943	1,601,734
QA Disposal Cell CSS	1 MR 94	15 JL 00	3,765,072	0	881,780	4,646,852
Long Term Maintenance						
Install Monitoring Wells	1 MR 98	1 SP 99				3,869,786
Initial Topographic Survey	1 JN 99	1 SP 99				45,000
Annual Env Monitoring	1 JA 01	1 JA 31	10,743,120	666,316	2,672,090	14,081,525

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ALTERNATIVES SUMMARY COST ESTIMATE (Continued)

ACTIVITY	START	FINISH	DIRECT TOTAL ($)	INDIRECT TOTAL ($)	TOTAL B,M,I* ($)	TOTAL PROJECT ($)
Annual Site Inspection	1 JA 01	1 JA 31				3,726,000
Annual Site Maintenance	1 JA 01	1 JA 31				1,863,000
Replace Fence at 15 years	15 SP 15	27 OC 15	94,500	0	11,529	106,029
	28 OC 30	20 DC 30	27,842	8,545	8,522	44,909
Replace Fence at 30 years	15 SP 15	27 OC 15	94,500	0	11,529	106,029
	28 OC 30	20 DC 30	27,842	8,545	8,522	44,909
Special Inspect at 15 years	1 JN 15	1 SP 15				90,000
Special Inspect at 30 years	1 JN 30	1 SP 30				90,000

* B,M,I = Bond, Margin, and Insurance

ALTERNATIVES SUMMARY COST ESTIMATE (Continued)

ACTIVITY	START	FINISH	DIRECT TOTAL ($)	INDIRECT TOTAL ($)	TOTAL B,M,I* ($)	TOTAL PROJECT ($)
DISPOSAL CELL/CHEMICAL PLANT OFF SITE						
Clear and Grub Light	1 MR 93	6 MA 93	176,727	43,562	52,060	274,350
Clear and Grub Heavy	7 MA 93	20 JN 93	161,021	42,946	47,769	251,736
Construct Retention Pond	1 MA 93	1 JN 93	45,292	11,382	13,273	69,947
Double HDPE Liner Pond	7 JN 93	15 JN 93	68,340	1,573	16,374	86,286
Water Control Dikes	1 FB 94	15 JN 94	835,213	62,114	210,154	1,107,481
Southeast Drainage Control	1 MR 94	15 JL 94	307,667	39,466	81,299	428,432
Haul Road Fill	1 AP 93	20 MA 93	235,004	61,495	69,440	365,939
Haul Road Base	21 MY 93	10 JN 93	186,472	10,424	46,113	243,009
Foundation Mobilization	15 MA 93	1 JL 93	74,280	0	17,396	91,676
Foundation Training	15 MA 93	19 NV 95	133,322	32,015	38,722	204,059
Foundation Demobilization	1 NV 95	1 JA 96	74,280	0	17,396	91,676
Remove Foundations (Phs 1,2,3)						
Phase 1	23 JN 93	6 OC 93				
Phase 2	23 NV 93	23 AP 94				
Phase 3	10 OC 95	18 NO 95				
Foundation Exc/Bckfll						
Phase 1 36%			110,300	24,767	31,633	166,700
Phase 2 50%			153,201	34,400	43,936	231,537
Phase 3 14%			42,893	9,631	12,301	64,825
Foundation Breakage						
Phase 1			348,574	77,654	99,823	526,051
Phase 2			484,131	107,853	138,643	730,626
Phase 3			135,557	30,199	38,820	204,575
Foundation Haul						
Phase 1			60,583	14,715	17,635	92,933
Phase 2			84,144	20,438	24,493	129,074
Phase 3			23,560	5,723	6,858	36,141

* B,M,I = Bond, Margin, and Insurance

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ALTERNATIVES SUMMARY COST ESTIMATE (Continued)

ACTIVITY	START	FINISH	DIRECT TOTAL ($)	INDIRECT TOTAL ($)	TOTAL B.M.I* ($)	TOTAL PROJECT ($)
Remove Underground Pipe	23 JN 93	18 NV 95	1,470,297	373,701	431,864	2,275,862
Backfill Pipe Trench			405,811	107,794	120,286	633,891
Remove Contaminated Material			165,381	42,855	48,769	257,005
Winter Shutdown - Chmcl Plnt	1 DC 93	1 MR 99	213,348	0	49,966	263,314
Contaminated Soil Excavation						
North Dump	9 MY 99	1 JN 99	67,100	16,273	19,526	102,899
Ash Pond	2 JN 99	6 JL 99	107,714	26,122	31,344	165,180
Frog Pond	11 AP 96	5 MY 96	68,866	16,701	20,040	105,607
Install Gravel Base						
Ash Pond	2 JN 99	6 JL 99	56,730	471	13,396	70,597
Frog Pond	11 AP 96	5 MY 96	11,346	94	2,679	14,119
Dewater Frog Pond	25 MR 96	10 AP 96	12,085	2,442	3,402	17,929
Surface Soil						
Phase 1	7 OC 93	1 NV 93	89,390	14,090	24,235	127,715
Phase 2	1 MR 95	2 AP 95	150,175	23,671	40,715	214,562
Phase 3	1 MR 96	2 AP 96	150,175	23,671	40,715	214,562
Mobilization Soil Excavation	7 OC 93	6 JL 99	17,107	0	4,006	21,113
Training Soil Excavation	15 SP 93	6 JL 99	138,758	33,875	40,431	213,063
Demob Soil Excavation	2 NV 93	1 AG 99	17,107	0	4,006	21,113
Equipment Decontamination	2 NV 93	1 AG 99	89,855	29,545	27,963	147,363
Reclamation Backfill						
Phase 1	2 NV 93	9 DC 93	164,957	38,855	47,733	251,545
Phase 2	3 AP 95	3 JN 95	253,441	59,697	73,337	386,475
Phase 3	3 AP 96	10 MY 96	172,037	40,523	49,782	262,342
Fence Removal	15 SP 00	7 NV 00	86,708	26,613	26,540	139,860
Reclamation Backfill	1 MR 00	15 AG 00	874,637	206,019	253,090	1,333,746
Topsoil	15 JN 00	15 SP 00	475,671	49,627	123,025	648,322
Seed and Mulch	20 JL 00	1 SP 00	68,502	9,603	18,292	96,397

* B.M.I = Bond, Margin, and Insurance

ALTERNATIVES SUMMARY COST ESTIMATE (Continued)

ACTIVITY	START	FINISH	DIRECT TOTAL ($)	INDIRECT TOTAL ($)	TOTAL B.M.I* ($)	TOTAL PROJECT ($)
Site Restoration Mob	1 FB 00	15 JN 00	28,524	0	6,680	35,204
Site Restoration Train	1 FB 00	1 SP 00	38,272	9,227	11,124	58,623
Site Restoration Demob	18 AG 00	15 SP 00	28,524	0	6,680	35,204
		OPERATIONS				
MSA Construction	18 FB 91	18 FB 92				0
Operate TSA	15 JL 93	15 JL 96				2,002,194
Operate MSA	18 JN 91	19 JA 96	3,294,600	889,475	979,910	5,163,986
Construct Decon Pad	1 MA 92	15 AG 92	30,199	4,654	8,163	43,016
Operate Decon Facility	16 AG 92	1 JA 00	730,558	229,907	224,941	1,185,407
Construct VRF	28 FB 94	28 FB 95	2,266,282	31,003	516,943	2,718,846
Operate VRF	1 MR 96	1 JL 99	1,679,419	356,716	476,863	2,512,998
Building 434 Load	1 MR 95	1 JA 00				191,973
Building 434 Haul PPE Mtrls	1 MR 95	1 JA 00				377,180
Operate WTP Off Site	16 AG 92	11 NV 99	2,076,801	404,834	581,199	3,062,834
Construct WTP			4,841,088	134,158	1,166,202	
Train 1	11 OC 91	15 AG 92				0
Train 2	28 FB 94	28 FB 95				1,187,918
Remove Haul Roads	2 OC 99	2 DC 99	147,766	35,969	43,031	226,766
Remove Control Dikes	21 SP 99	10 NV 99	353,181	84,440	102,491	540,112
Remove TSA	2 AG 99	15 SP 99	174,641	39,076	48,818	262,536
Remove MSA	2 AG 99	20 SP 99	201,046	45,966	57,850	304,861
Remove Treatment Facility	2 JN 99	2 JL 99	105,633	28,029	31,304	164,965
Remove Water Treatment Facility	11 NV 99	2 DC 99	63,673	18,927	19,345	101,945
Remove VRF Facility	21 SP 99	22 OC 99	105,633	28,029	31,304	164,965
Haul to Size Reduction	1 MR 96	1 JL 99	481,647	116,988	140,200	738,835
Transport Rubble	1 MR 95	1 JN 99	227,150	55,173	66,120	348,442
Haul Clay/Soil Vitrif Process	1 MR 95	1 JN 99	694,467	136,225	194,548	1,025,240

* B,M,I = Bond, Margin, and Insurance

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ALTERNATIVES SUMMARY COST ESTIMATE (Continued)

ACTIVITY	START	FINISH	DIRECT TOTAL ($)	INDIRECT TOTAL ($)	TOTAL B,M,I* ($)	TOTAL PROJECT ($)
OFF SITE						
Mobilization	1 JA 9495	1 MR 95	269,975	0	63,228	333,203
Demobilization	1 JN 99	1 JA 00	269,975	0	63,228	333,203
Training	1 JA 95	1 JA 00	406,876	104,112	119,673	630,662
Load/Haul Material	1 MR 95	1 JA 00	16,680,043	2,347,493	4,456,249	23,483,785
Surge Pile Maintenance	1 MR 95	1 JA 00	1,332,976	339,876	391,782	2,064,635
Winter Load at VRF	1 DC 95	1 MR 99	313,415	77,798	91,622	482,835
Guard Services	1 MR 95	1 JA 00	351,120	141,792	115,440	608,352
Construct RR Siding	1 NV 94	1 DC 94	2,285,000	0	535,147	2,820,147
Construct Transfer Pads	1 OC 94	1 DC 94	222,300	0	52,063	274,363
Equipment Decon	1 SP 99	1 JA 00	48,310	15,080	15,080	78,470
TOTALS			46,801,117	7,174,580	12,619,027	66,946,441
PRESENT WORTH						38,732,274
Disposal/Transport Clive	1 MR 94	1 JA 00				214,360,452
TOTAL						214,360,452
PRESENT WORTH						116,060,981
Disposal/Transport Hanford	1 MR 94	1 JA 00				142,919,400
TOTAL						142,919,400
PRESENT WORTH						77,380,718

* B,M,I = Bond, Margin, and Insurance

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ALTERNATIVES SUMMARY COST ESTIMATE (Continued)

ACTIVITY	START	FINISH	DIRECT TOTAL ($)	INDIRECT TOTAL ($)	TOTAL B,M,I* ($)	TOTAL PROJECT ($)
DISPOSAL CELL/CHEMICAL PLANT VIT						
Clear and Grub Light	1 MR 93	6 MA 93	178,727	43,562	52,080	274,350
Clear and Grub Heavy	7 MA 93	20 JN 93	161,021	42,946	47,769	251,736
Construct Retention Pond	1 MA 93	1 JN 93	45,292	11,382	13,273	69,947
Double HDPE Liner Pond	7 JN 93	15 JN 93	68,340	1,573	16,374	86,288
Water Control Dikes	1 FB 94	15 JN 94	835,213	62,114	210,154	1,107,481
Southeast Drainage Control	1 MR 94	15 JL 94	307,667	39,466	81,299	428,432
Haul Road Fill	1 AP 93	20 MA 93	235,004	61,495	69,440	365,939
Haul Road Base	21 MY 93	10 JN 93	186,472	10,424	46,113	243,009
Foundation Mobilization	15 MA 93	1 JL 93	74,280	0	17,396	91,676
Foundation Training	15 MA 93	18 NV 95	133,322	32,015	38,722	204,059
Foundation Demobilization	1 NV 95	1 JA 96	74,280	0	17,396	91,676
Remove Foundations (Phs 1,2,3)						
Phase 1	23 JN 93	6 OC 93				
Phase 2	23 NV 93	23 AP 94				
Phase 3	10 OC 95	18 NV 95				
Foundation Exc/Bckfll						
Phase 136%			110,300	24,767	31,633	166,700
Phase 250%			153,201	34,400	43,936	231,537
Phase 314%			42,893	9,631	12,301	64,825
Foundation Breakage						
Phase 1			348,574	77,654	99,823	526,051
Phase 2			484,131	107,853	138,643	730,626
Phase 3			135,557	30,199	38,820	204,575
Foundation Haul						
Phase 1			60,583	14,715	17,635	92,933
Phase 2			84,144	20,438	24,493	129,074
Phase 3			23,560	5,723	6,858	36,141

* B,M,I = Bond, Margin, and Insurance

ALTERNATIVES SUMMARY COST ESTIMATE (Continued)

ACTIVITY	START	FINISH	DIRECT TOTAL ($)	INDIRECT TOTAL ($)	TOTAL B.M.I* ($)	TOTAL PROJECT ($)
Remove Underground Pipe	23 JN 93	1 OC 94	1,470,297	373,701	431,864	2,275,862
Backfill Pipe Trench			405,811	107,794	120,286	633,891
Remove Contaminated Material			165,381	42,855	48,769	257,005
Winter Shutdown - Chmcl Plnt	1 DC 93	1 MR 99	213,348	0	49,966	263,314
Contaminated Soil Excavation						
North Dump	1 JL 93	1 AG 93	67,100	16,273	19,526	102,899
Ash Pond	2 JN 99	6 JL 99	107,714	26,122	31,344	165,180
Frog Pond	11 AP 96	5 MY 96	68,866	16,701	20,040	105,607
Install Gravel Base						
Ash Pond	2 JN 99	6 JL 99	56,730	471	13,396	70,597
Frog Pond	11 AP 96	5 MY 96	11,346	94	2,679	14,119
Dewater Frog Pond	25 MR 96	10 AP 96	12,085	2,442	3,402	17,929
South dump	15 OC 97	1 DC 97	149,210	36,186	43,420	228,816
Surface Soil						
Phase 1	27 FB 94	23 AG 94	255,060	40,204	69,151	364,414
Phase 2	1 MR 96	2 AP 96	150,176	23,671	40,715	214,562
Mobilization Soil Excavation	7 OC 93	6 JL 99	17,107	0	4,006	21,113
Training Soil Excavation	15 SP 93	6 JL 99	138,756	33,876	40,431	213,063
Demob Soil Excavation	2 NV 93	1 AG 99	17,107	0	4,006	21,113
Equipment Decontamination	2 NV 93	1 AG 99	89,855	29,545	27,963	147,363
Reclamation Backfill						
Phase 1	24 AP 94	1JUL94	418,398	98,553	121,070	638,021
Phase 2	3 AP 96	10 MY 96	172,066	40,530	49,790	262,386
Fence Removal & Installation	15 SP 00	27 OC 00	94,500	0	11,529	106,029
	28 OC 00	20 DC 00	86,708	26,613	26,540	139,860
Reclamation Backfill	1 MR 00	15 AG 00	874,637	206,019	253,090	1,333,746
Topsoil	15 JN 00	15 SP 00	475,671	49,627	123,025	648,322
Seed and Mulch	20 JL 00	1 SP 00	68,502	9,603	18,292	96,397

* B.M.I = Bond, Margin, and Insurance

ALTERNATIVES SUMMARY COST ESTIMATE (Continued)

ACTIVITY	START	FINISH	DIRECT TOTAL ($)	INDIRECT TOTAL ($)	TOTAL B,M,I* ($)	TOTAL PROJECT ($)
Site Restoration Mob	1 FB 00	15 JN 00	28,524	0	6,680	35,204
Site Restoration Train	1 FB 00	1 SP 00	38,272	9,227	11,124	58,623
Site Restoration Demob	16 AG 00	15 SP 00	28,524	0	6,680	35,204
OPERATIONS						
MSA Construction	18 FB 91	18 FB 92				0
Operate MSA	18 JN 91	19 JA 96	3,294,600	889,475	979,910	5,163,986
Operate TSA	15 JL 93	15 JL 95				2,002,194
Construct Decon Pad	1 MA 92	16 AG 92	30,189	4,654	8,163	43,016
Operate Decon Facility	16 AG 92	1 JA 00	730,558	229,907	224,941	1,185,407
Construct VRF	28 FB 94	28 FB 95	2,266,282	31,003	538,024	2,835,309
Operate VRF	1 MR 95	1 JL 99	1,679,419	356,716	476,863	2,512,998
Building 434 Load	1 MR 95	1 JA 00				181,973
Building 434 Haul PPE Mtrls	1 MR 95	1 JA 00				377,180
Operate WTP On Site	16 AG 92	11 NV 99	2,343,733	465,326	657,882	3,466,941
Construct WTP			4,841,098	134,156	1,165,202	
Train 1	11 OC 91	16 AG 92				0
Train 2	28 FB 94	28 FB 95				1,187,918
Haul to Size Reduction	1 MR 95	1 JL 99	481,647	116,988	140,200	738,835
Transport Rubble	1 MR 95	1 JN 99	227,150	55,173	66,120	348,442
Haul Clay/Soil Vitrif Process	1 MR 95	1 JN 99	694,467	136,225	194,548	1,025,240
Haul Rubble to Cell	1 MR 95	1 AG 99	1,953,572	482,041	570,421	3,006,035
Transport Soils etc.	1 MR 95	1 AG 99	617,847	143,754	178,367	939,968
Additional Haul Cost TSA	1 MR 95	1 AG 99	330,557	76,910	95,429	502,898
Haul Treated Waste to Cell						
Vitrification Process	1 MR 95	1 JN 99	1,816,903	430,489	526,339	2,773,731
Remove Haul Roads	2 OC 99	2 DC 99	147,766	35,969	43,031	226,765
Remove Control Dikes	21 SP 99	10 NV 99	353,181	84,440	102,491	540,112
Remove TSA	2 AG 99	15 SP 99	174,641	38,076	49,819	262,536

* B,M,I = Bond, Margin, and Insurance

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ALTERNATIVES SUMMARY COST ESTIMATE (Continued)

ACTIVITY	START	FINISH	DIRECT TOTAL ($)	INDIRECT TOTAL ($)	TOTAL B,M,I* ($)	TOTAL PROJECT ($)
Remove MSA	2 AG 99	20 SP 99	201,046	45,965	57,850	304,861
Remove Treatment Facility	2 JN 99	2 JL 99	105,633	28,029	31,304	164,965
Remove Water Treatment Facility	11 NV 98	2 DC 99	63,673	18,927	19,345	101,945
Remove VRF Facility	21 SP 99	22 OC 99	105,633	28,029	31,304	164,965
Cell Operations	1 MR 95	2 DC 99				
Place Soil/Rubble			3,091,781	859,293	925,341	4,876,415
Place Vit Waste			950,724	247,445	280,611	1,478,780
Furnish Clay Binder	1 MR 95	1 JN 99	217,817	48,694	62,417	328,928
TWO CELL						
Fill Performance Tests	1 MR 92	1 JL 92	449,829	10,770	107,872	568,472
Borrow Source Evaluation			219,485	16,098	55,173	290,753
Liner Compatibility Tests			16,000	0	3,747	19,747
Mob/Demob			20,192	0	4,728	24,921
Foundaton Phase 1	5 JL 94	30 NV 94				
Foundation Phase 2	11 MY 96	21 MY 97				
Prepare Cell Subgrade			15,444	4,169	4,593	24,206
Cell Subgrade Excavation/Fill			248,586	48,876	69,666	367,128
Place Cell Foundation Clay			2,139,479	464,666	609,891	3,214,036
Cell Foundation HDPE Liner			1,064,340	23,348	254,736	1,342,424
Cell Foundation Gravel			1,810,325	117,564	451,511	2,379,400
Cell Collection/Discharge Pipe			97,411	16,196	26,607	140,214
Cell Foundation Sand			611,987	78,062	161,609	851,658
Cell Foundation Concrete Summ.			67,057	14,955	19,207	101,219
COVER						
Cover Phase 1	1 FB 95	17 DC 97				
Cover Phase 2	1 MY 97	15 JN 00				
3ft Frost Protection Layer Side			1,936,151	432,840	554,918	2,923,909
4ft Clay Cover Side			2,667,022	579,241	760,275	4,006,538

* B,M,I = Bond, Margin, and Insurance

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ALTERNATIVES SUMMARY COST ESTIMATE (Continued)

ACTIVITY	START	FINISH	DIRECT TOTAL ($)	INDIRECT TOTAL ($)	TOTAL B,M,I* ($)	TOTAL PROJECT ($)
4ft Clay Cover Top			234,463	50,922	66,837	352,223
2ft Frost Protection Cover Top			113,891	25,461	32,636	171,989
Install HDPE Side			1,015,675	28,928	244,645	1,289,248
Install HDPE Top			87,480	1,919	20,937	110,336
Filter Side			589,686	73,434	155,303	818,423
Rip Rap Side			1,034,716	117,944	269,953	1,422,613
Choke Rock Side			633,238	91,941	169,837	895,016
Filter Top			102,554	12,771	27,009	142,334
Choke Rock Top			110,128	15,990	29,537	155,655
Install Drain Top			102,554	12,771	27,009	142,334
VITRIFICATION CELL						
Foundation	5 JL 94	2 NV 94				
Prepare Cell Subgrade			6,135	1,656	1,825	9,616
Cell Subgrade Excavation/Fill			133,242	26,198	37,341	196,780
Cell Subgrade Borrow			526,747	117,758	150,943	795,448
Cover	2 JN 99	11 JN 00				
Filter			102,554	12,771	27,009	142,334
Clay Cover			483,581	105,027	137,852	726,460
Frost Protection			341,674	76,383	97,909	515,966
Choke Rock			550,642	79,946	147,684	778,274
Place Sod VIT	15 FB 00	15 JL 00	1,085,760	149,681	289,340	1,524,781
Haul Road Maintenance	10 JN 93	15 JL 00	250,957	50,520	70,606	372,083
Cell Dewatering	1 MR 94	1 MR 00	570,412	152,596	169,329	892,337
Clear Cover Borrow	1 OC 94	1 DC 94	87,500	0	10,675	98,176
Mobilization Cell	1 FB 94	1 JN 96	502,139	0	117,601	619,739
Training Cell	1 FB 94	1 JL 00	252,529	61,647	73,580	387,756
Winter Shutdown - Cell	1 DC 94	1 MR 00	2,195,865	0	514,272	2,710,137
Decontamination - Cell	1 JN 99	1 FB 00	294,071	96,693	91,517	482,280

* B,M,I = Bond, Margin, and Insurance

ALTERNATIVES SUMMARY COST ESTIMATE (Continued)

ACTIVITY	START	FINISH	DIRECT TOTAL ($)	INDIRECT TOTAL ($)	TOTAL B.M.I* ($)	TOTAL PROJECT ($)
Demobilization - Cell	1 JN 99	1 AG 00	502,139	0	117,601	619,739
Disposal Cell Engineering	1 MR 92	1 JA 94	1,297,791	0	303,943	1,601,734
QA Disposal Cell VIT	5 JL 94	15 JN 00	3,044,037	0	712,913	3,756,950
Long Term Maintenance						
Install Monitoring Wells	1 MR 98	1 SP 99				3,669,786
Initial Topographic Survey	1 JN 99	1 SP 99				45,000
Annual Env Monitoring	1 JA 01	1 JA 31	10,743,120	666,316	2,672,090	14,081,525
Annual Site Inspection	1 JA 01	1 JA 31				3,726,000
Annual Site Maintenance	1 JA 01	1 JA 31				1,863,000
Replace Fence at 15 years	15 SP 15	27 OC 15	94,500	0	11,529	106,029
	28 OC 30	20 DC 30	27,842	8,545	8,522	44,909
Replace Fence at 30 years	15 SP 15	27 OC 15	94,500	0	11,529	106,029
	28 OC 30	20 DC 30	27,842	8,545	8,522	44,909
Special Inspect at 15 years	1 JN 15	1 SP 15				90,000
Special Inspect at 30 years	1 JN 30	1 SP 30				90,000
TOTAL						112,472,507
PRESENT WORTH						55,052,390

* B,M,I = Bond, Margin, and Insurance

ALTERNATIVES SUMMARY COST ESTIMATE (Continued)

ACTIVITY	START	FINISH	DIRECT TOTAL ($)	INDIRECT TOTAL ($)	TOTAL B,M,I* ($)	TOTAL PROJECT ($)
DISPOSAL CELL/CHEMICAL PLANT						
Operate MSA	19 JN 91	19 JA 96	3,294,600	889,475	979,910	5,163,986
Operate TSA	15 JL 93	15 JL 96				2,002,194
Construct Decon Pad	1 MR 92	15 AG 92	30,199	4,654	8,163	43,016
Operate Decon Facility	16 AG 92	1 JL 96	404,735	108,056	120,096	632,887
Operate WTP On Site	16 AG 92	11 NV 96	1,382,802	274,542	388,150	2,045,495
Long Term Maintenance						
Annual Env Monitoring	1 JA 97	1 JA 27	10,743,120	666,316	2,672,090	14,081,525
Annual Site Inspection	1 JA 97	1 JA 27				1,863,000
Annual Site Maintenance	1 JA 97	1 JA 27				931,500
TOTAL						26,763,604
PRESENT WORTH						10,014,607

* B,M,I = Bond, Margin, and Insurance

ALTERNATIVES SUMMARY COST ESTIMATE (Continued)

ACTIVITY	START	FINISH	DIRECT TOTAL ($)	INDIRECT TOTAL ($)	TOTAL B,M,I* ($)	TOTAL PROJECT ($)
RAFFINATE PITS VIT						
VIT Bench Scale Testing	15 JA 92	15 JA 93	2,517,000	0	589,481	3,106,481
VIT Pilot Scale Testing	1 JN 92	15 SP 93	4,150,000	0	971,930	5,121,930
Construct Vitr Facility	3 OC 93	25 JA 9	20,498,665	0	4,797,977	25,623,582
Operate Vitr Facility	1 MR 95	1 JN 99	13,682,643	2,141,852	3,706,097	19,530,591
Treatment Facility Mobe VIT	15 SP 93	15 FB 95	205,094	0	48,033	253,127
Treatment Facility Train VIT	3 OC 93	1 JN 99	277,504	67,744	80,857	426,105
Treatment Facility Demobe VIT	15 JA 95	15 JL 99	205,094	0	48,033	253,127
Mobilization	2 AG 94	1 MY 95	99,487	0	23,300	122,787
Training	2 AG 94	5 NV 99	208,128	50,808	60,643	319,579
Site Preparation						
Clear and Grub Raffinate Pits	13 SP 94	15 DC 94	96,518	24,822	28,418	149,758
Clear and Grub Haul Roads	13 SP 94	27 SP 94	30,265	8,105	8,986	47,356
Berm Construction (Const. Basin)	16 DC 94	3 JA 95	30,817	7,578	8,992	47,387
Temporary Water Control Ditches	16 DC 94	3 JA 95	1,249	218	343	1,810
Double HDPE Liner for Basin	4 JA 95	17 JA 95	124,152	2,857	29,745	156,754
Haul Road Sub-Base	28 SP 94	3 NV 94	61,396	15,815	18,083	95,294
Haul Road Aggregate-Base	28 SP 94	3 NV 94	82,464	3,879	20,222	106,565
Dredge and Dewater All Pits VIT	1 MR 95	1 DC 97	4,410,650	227,347	1,086,219	5,724,216
Pit 1						
T Section	2 MY 95	11 JN 95	27,295	7,018	8,036	42,348
Remove Base	2 MY 95	11 JN 95	69,658	16,415	20,158	106,232
Pit 2						
T Section	1 JL 95	11 AG 95	27,295	7,018	8,036	42,348
Remove Base	1 JL 95	11 AG 95	69,658	16,415	20,158	106,232
Pit 3						
Remove Base	15 AP 97	15 SP 97	445,925	105,081	129,045	680,051

* B,M,I = Bond, Margin, and Insurance

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ALTERNATIVES SUMMARY COST ESTIMATE (Continued)

ACTIVITY	START	FINISH	DIRECT TOTAL ($)	INDIRECT TOTAL ($)	TOTAL B,M,I* ($)	TOTAL PROJECT ($)
Pit 4						
Remove Base	1 MR 98	1 DC 98	808,147	190,438	233,869	1,232,454
Remove Rubble	1 DC 98	21 DC 98	75,099	19,731	22,209	117,040
HEPA Ventilation	1 AP 95	7 MY 95	98,896	0	23,161	122,057
Temporary Haul Road Pit	2 MY 95	1 JN 98	285,371	9,324	69,018	363,713
Haul Road Maintenance	2 MY 95	5 NV 99	136,083	27,407	38,288	201,780
Remediate Pit 1and Pit 2	11 AG 95	1 NV 95	434,644	87,413	124,608	656,664
Remediate Pit 3and Pit 4ind	1 MR 99	15 JN 99	582,568	130,586	167,016	880,161
Remediate Pit 3and Pit 4fnl	16 JN 99	16 AG 99	325,385	46,838	87,175	459,398
Topsoil	1 AG 99	5 NV 99	642,798	67,064	166,250	876,111
Seed and Mulch	1 OC 99	10 NV 99	71,441	10,015	19,077	100,533
Haul Road Decontamination	1 MR 99	20 AP 99	113,798	27,700	33,139	174,637
Dewatering Phase 1	1 MY 95	1 NV 95	102,823	24,984	29,932	157,739
Dewatering Phase 2	15 AP 97	16 AG 99	479,840	116,593	139,685	736,117
Equipment Decontamination	22 DC 98	15 MY 99	33,860	12,534	10,866	57,260
Demobilization	22 DC 98	5 NV 99	99,487	0	23,300	122,787
Winter Shutdown	1 DC 95	1 MR 99	328,770	0	76,998	405,768
TOTALS			10,409,966	1,273,984	2,734,976	68,727,969
PRESENT WORTH						42,184,374

* B,M,I = Bond, Margin, and Insurance

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ALTERNATIVES SUMMARY COST ESTIMATE (Continued)

ACTIVITY	START	FINISH	DIRECT TOTAL ($)	INDIRECT TOTAL ($)	TOTAL B,M,I* ($)	TOTAL PROJECT ($)
RAFFINATE PITS CSS						
CSS Bench Scale Testing	15 JA 92	15 JA 93	851,000	0	199,304	1,050,304
CSS Pilot Scale Testing	1 JN 92	15 SP 93	861,000	0	201,646	1,062,646
Construct CSS Facility	3 OC 93	25 JA 95	2,510,000	0	587,842	3,097,842
Operate CSS Facility	1 MR 95	1 JN 99	10,999,447	504,764	2,694,286	14,198,498
Treatment Facility Mobe CSS	15 SP 93	15 FB 95	102,547	0	24,017	126,564
Treatment Facility Train CSS	3 OC 93	1 JN 99	138,752	33,872	40,428	213,052
Treatment Facility Demobe CSS	15 JA 95	15 JL 99	102,547	0	24,017	126,564
Mobilization	2 AG 94	1 MY 95	99,487	0	23,300	122,787
Training	2 AG 94	5 NV 99	208,128	50,808	60,643	319,579
Site Preparation						
Clear and Grub Raffinate Pits	13 SP 94	16 DC 94	96,518	24,822	28,418	149,758
Clear and Grub Haul Roads	13 SP 94	27 SP 94	30,265	8,105	8,986	47,356
Berm Construction (Const. Basin)	16 DC 94	3 JA 95	30,817	7,578	8,992	47,387
Temporary Water Control Ditches	16 DC 94	3 JA 95	1,249	218	343	1,810
Double HDPE Liner for Basin	4 JA 95	17 JA 95	124,152	2,857	29,745	156,754
Haul Road Sub-Base	28 SP 94	3 NV 94	61,396	15,815	18,093	95,294
Haul Road Aggregate-Base	28 SP 94	3 NV 94	82,464	3,879	20,222	106,565
Dredge All Pits CSS	1 MR 95	1 DC 97	2,472,700	117,805	606,696	3,197,201
Pit 1						
T Section	2 MY 95	11 JN 95	27,295	7,018	8,036	42,349
Remove Base	2 MY 95	11 JN 95	69,658	16,415	20,158	106,232
Pit 2						
T Section	1 JL 95	11 AG 95	27,295	7,018	8,036	42,349
Remove Base	1 JL 95	11 AG 95	69,658	16,415	20,158	106,232
Pit 3						
Remove Base	15 AP 97	15 SP 97	445,925	105,081	129,045	680,051

* B,M,I = Bond, Margin, and Insurance

ALTERNATIVES SUMMARY COST ESTIMATE (Continued)

ACTIVITY	START	FINISH	DIRECT TOTAL ($)	INDIRECT TOTAL ($)	TOTAL B.M.I* ($)	TOTAL PROJECT ($)
Pit 4						
Remove Base	1 MR 98	1 DC 98	808,147	190,438	233,869	1,232,454
Remove Rubble	1 DC 98	21 DC 98	76,099	19,731	22,209	117,040
HEPA Ventilation	1 AP 95	7 MY 95	98,896	0	23,161	122,057
Temporary Haul Road Pit	2 MY 95	1 JN 98	285,371	9,324	69,018	363,713
Haul Road Maintenance	2 MY 95	5 NV 99	136,083	27,407	38,289	201,780
Remediate Pit 1and Pit 2	11 AG 95	1 NV 95	434,644	97,413	124,608	656,664
Remediate Pit 3and Pit 4intl	1 MR 99	15 JN 99	582,568	130,566	167,016	880,151
Remediate Pit 3and Pit 4fnl	16 JN 99	16 AG 99	325,385	46,838	87,175	459,398
Topsoil	1 AG 99	5 NV 99	642,798	67,064	166,250	876,111
Seed and Mulch	1 OC 99	10 NV 99	71,441	10,015	19,077	100,533
Haul Road Decontamination	1 MR 99	20 AP 99	113,798	27,700	33,139	174,637
Dewatering Phase 1	1 MY 95	1 NV 95	102,823	24,984	29,932	157,739
Dewatering Phase 2	15 AP 97	16 AG 99	479,840	116,593	139,685	736,117
Equipment Decontamination	22 DC 98	15 MY 99	33,860	12,534	10,866	57,260
Demobilization	22 DC 98	5 NV 99	99,487	0	23,300	122,787
Winter Shutdown	1 OC 95	1 MR 99	328,770	0	76,998	405,768
TOTALS	2 AG 94	21 DC 98	8,466,016	1,164,441	2,255,453	31,761,360
PRESENT WORTH						17,636,631

* B.M.I = Bond, Margin, and Insurance

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ALTERNATIVES SUMMARY COST ESTIMATE (Continued)

ACTIVITY	START	FINISH	TOTAL PROJECT ($)	PRESENT WORTH ($)
VICINITY PROPERTIES				
VP - Army Properties 5 & 6	15 MY 99	27 AG 99	342,916	145,396
VP - Busch Properties B3/4/5	1 AG 95	1 DC 95	357,690	222,125
VP - Army Properties 1,2,3				
Busch Lakes 34, 35, 36	1 MR 98	1 JN 98	400,000	186,800
			1,100,606	554,322

B,M,I = Bond, Margin, and Insurance

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